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(71) Applicants (for all designated States except US):
GIRINDUS AG [DE/DE]; Buchenallee 20, 51427 Bergisch-Gladbach (DE). CENTRE NATIONAL DE LA RECHERCHE SCIENTIFIQUE [FR/FR]; 3, rue Michel Ange, F-75794 Paris Cédex 16 (FR). UNIVERSITY OF MONTPELLIER II [FR/FR]; 2, Place E. Bataillon, F-34095 Montpellier Cedex 5 (FR).

(72) Inventors; and

(75) Inventors/Applicants (for US only): ADAMO, Ilaria [IT/IT]; Via dei Ciani 26, I-34034 Fagagna (IT). DUEYMES, Cécile [FR/FR]; 4, rue via de la Viadène, F-12000 Rodez (FR). SCHÖNBERGER, Andreas [DE/DE]; Grabenkamp 6, 38539 Münden / Aller (DE). IM-BACH, Jean-Louis [FR/FR]; 91, impasse des Lucques, F-34060 Montpellier (FR). MEYER, Albert [FR/FR]; 11, rue des Rascasses, F-34470 Perols (FR). MORVAN, Francois [FR/FR]; 17, rue de l'Opale, F-34170 Castelnau le Lez (FR). DEBART, Françoise [FR/FR]; 5, allée

du Plein Sud, F-34980 Combaillaux (FR). VASSEUR, Jean-Jacques [FR/FR]; 5, allée du Plein Sud, F-34980 Combaillaux (FR). LANGE, Meinolf [DE/DE]; c/o Girindus AG - Werk Künsebeck, Kantstrasse 2, 33777 Halle/Westf. (DE). LINK, Fritz [DE/DE]; c/o Girindus AG, Buchenallee 20, 51427 Bergisch-Gladbach (DE).

(74) Agents: SCHREIBER, Christoph et al.; Patent Attorneys, von Kreisler Selting Werner, P.O. Box 10 22 41, 50462 Cologne (DE).

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(54) Title: METHOD FOR PREPARING OLIGONUCLEOTIDES

(57) Abstract: A method for preparing an oligonucleotide comprising the steps of a) providing a 3'-protected compound having the formula: wherein B is a heterocyclic base R2 is H, a protected 2'-hydroxyl group, F, a protected amino group, an O-alkyl group, an O-substituted alkyl, a substituted alkylamino or a C4'-O2'-methylene linkage R3 is OR'3, NHR"3, NR"3R'"3, a 3'-protected nucleotide or a 3'-protected oligonucleotide, R'3 is a hydroxyl protecting group, R"3, R'"3 are independently an amine protecting group, b) reacting said compound with a nucleotide derivative having a 5'-protection group in the presence of a solid supported activator to give an elongated oligonucleotide with a P(III)-internucleotide bond c) optionally processing the elongated oligonucleotide with a P(III)-internucleotide bond by either or both of steps c1) and c2) in any sequence c1) capping preferably by reacting with a solid supported capping agent c2) oxidizing preferably by reacting the oligonucleotide with a solid supported oxidizing reagent d) removing the 5'-protection group.

Method for preparing oligonucleotides

The present invention relates to a method for preparing oligonucleotides.

The synthesis of oligonucleotides has been the subject of investigations for a long period of time. Automated synthesis procedures have been developed and 5 apparatus for the automated syntheses are commercially available. Most of these procedures have been developed for rather small quantities of oligonucleotides (in the range of mg). These amounts are sufficient for most investigational purposes.

Especially with the development of antisense therapeutics, large scale synthesis 10 became a matter of considerable importance. Although relative large scale amounts of oligonucleotides have been obtained by scale-up of solid phase synthesis procedures, these technologies show major limitations especially high costs for reagents and materials, e.g. the solid phase bound starting oligonucleotide.

15 With scale-up, the reaction time of each step of the synthesis increases.

Furthermore oligonucleotides synthesis by standard solid phase synthesis results 20 in a contamination of the desired full length compound by failure sequences arising from incomplete reaction during the synthesis cycle. At large scales the purification of the crude oligonucleotide involves complicated isolation and chromatographic purification of the final product.

In general, synthesis methods for oligonucleotides consist of a four-step procedure for the elongation of the oligonucleotide

1. Coupling
2. Capping
- 25 3. Oxidation
4. Deprotection of the protected hydroxyl group for the next reaction cycle.

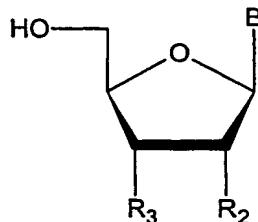
One object of the present invention is to provide a method for the preparation of oligonucleotides suitable for large scale (kilogram to tons) synthesis.

A further object of the present invention is to provide a method for the preparation 30 of oligonucleotides avoiding complicated purification steps, especially chromatographic purifications, especially during synthesis cycles.

A further object of the invention is to provide a method for the preparation of oligonucleotides allowing an effective convergent synthesis.

In one embodiment this object is solved by a liquid phase synthesis method, comprising the steps of

a) providing a 3'-protected compound having the formula:



5 wherein

B is a heterocyclic base

R₂ is H, a protected 2'-hydroxyl group, F, a protected amino group, an O-alkyl group, an O-substituted alkyl, a substituted alkylamino or a C4'-O₂'-methylen linkage

10 R₃ is OR'₃, NHR"₃, NR"sub>3"R'"₃, a 3'-protected nucleotide or a 3'-protected oligonucleotide,

R'₃ is a hydroxyl protecting group,

R"₃, R'"₃ are independently an amine protecting group,

15 b) reacting said compound with a nucleotide derivative having a 5'-protection group in the presence of a solid supported activator to give an elongated oligonucleotide with a P(III)-internucleotide bond

c) optionally processing the elongated oligonucleotide with a P(III)-internucleotide bond by either or both of steps c1) and c2) in any sequence

c1) capping, preferably by reacting with a solid supported capping agent

20 c2) oxidizing, preferably by reacting the oligonucleotide with a solid supported oxidizing reagent

d) removing the 5'-protection group.

The method of the present invention is a solution phase synthesis wherein at least some of the reagents are solid supported. "Solid supported" covers covalently bound reagents and reagents bound to a solid support by ionic forces.

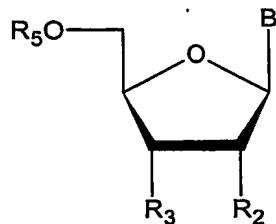
In a preferred embodiment, step d) is effected by treatment with a solid supported agent or removing the 5'-protection group with a removal agent followed

by addition of a solid supported scavenger or followed by extraction.

In most cases coupling occurs of a 5'-OH-synthon with a 3'-phosphorous-synthon. Alternatively coupling of a 5'-phosphorous-synthon with a 3'-OH-synthon is also possible. Therefore in a further embodiment the invention com-

5 comprises a method comprising the steps of

a) providing a 5'-protected compound having the formula:



wherein

B is a heterocyclic base

10 R₂ is H, a protected 2'-hydroxyl group, F, a protected amino group, an O-alkyl group, an O-substituted alkyl, a substituted alkylamino or a C4'-O2' methylen linkage

R₃ is OH, NH₂

15 R₅ is a hydroxyl protecting group, a 5'-protected nucleotide or a 5'-protected oligonucleotide

b) reacting said compound with a nucleotide derivative having a 3'-protection group in the presence of a solid supported activator to give an elongated oligonucleotide with a P(III)-internucleotide bond

20 c) optionally processing the elongated oligonucleotide with a P(III)-internucleotide bond by either or both of steps c1) and c2) in any sequence

c1) capping, preferably by reacting with a solid supported capping agent

c2) oxidizing, preferably by reacting the oligonucleotide with a solid supported oxidizing reagent

d) removing the 3'-protection group.

25 In a preferred embodiment, step d) is effected by treatment with a solid supported agent or removing the 3'-protection group with a removal agent followed by addition of a solid supported scavenger or followed by extraction.

In further embodiments, it is possible to couple a 3'-phosphorous synthon with a 3'-OH synthon to form a non-natural 3'-3'-internucleosidic linkage. For the synthesis of non-natural 5'-5'-internucleosidic linkages it is possible to react a 5'-phosphorous synthon with a 5'-OH synthon. These non-natural internucleosidic linkages show increased nuclease resistance.

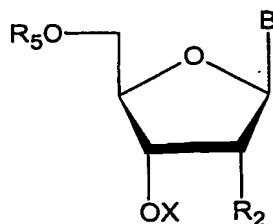
Step a)

B, the heterocyclic base can be a natural nucleobase or a modified one including a non-base residue. The natural nucleobases are adenine, guanine, thymine, cytosine and uracil. In general these bases need protection groups during the synthesis. Suitable protected nucleobases are known to persons skilled in the art for example N-4-benzoylcytosine, N-6-benzoyl adenine, N-2-isobutiryl guanine, N-4-acetyl or isobutyryl cytosine, N-6-phenoxyacetyl adenine, N-2-tert-butyl phenoxyacetyl guanine. Suitable non-base residues include for example Hydrogen, H leading to the 1',2'-dideoxyribose (dSpacer from Glen Research) which can be used as linker or to mimic abasic sites in an oligonucleotide (Takeshita et al., J. Biol. Chem., 1987, 262, 10171).

Furthermore, it is also possible to use isomers of nucleosides such as L, D, α , β and the like.

A suitable protection for the 2'-hydroxyl-group include but are not limited to tert-butyl dimethylsilyl (TBDMS), triisopropylsilyloxymethyl (TOM), fluorophenyl-metoxyppiperidinyl (FPMP).

Suitable protecting groups for the 3'-hydroxyl-group include but are not limited to tert-butyl dimethylsilyl (TBDMS), levulinyl, benzoyle. This compound is then reacted with a nucleotide derivative with a 3'-phosphorous-synthon. The nucleotide derivative preferably has the following formula



(Formula III)

wherein

X is a P(III)-function

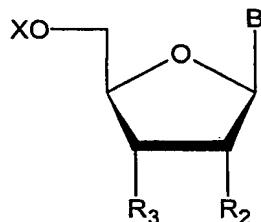
B is a heterocyclic base

R₂ is H, a protected 2'-hydroxyl group, F, a protected amino group, an O-alkyl group, an O-substituted alkyl, a substituted alkylamino or a C4'-O2'-methylen linkage

5

R₅ is a hydroxyl protecting group, a 5'-protected nucleotide or a 5'-protected oligonucleotide.

In the second embodiment, the nucleotide derivative preferably has the following formula



10

(Formula IV)

wherein

X is a P(III)-function

B is a heterocyclic base

15 R₂ is H, a protected 2'-hydroxyl group, F, a protected amino group, an O-alkyl group, an O-substituted alkyl, a substituted alkylamino or a C4'-O2'-methylen linkage

R₃ = OR'₃, NHR"′₃, NR"′₃R'''₃, a 3'-protected nucleotide or a 3'-protected oligonucleotide,

20 R'′₃ is a hydroxyl protecting group,

R"′₃, R'''₃ are independently an amine protecting group,

R'′₃ is a hydroxyl protecting group, a 3'-protected nucleotide or a 3'-protected oligonucleotide

Step b): The coupling step

25 In step b) the coupling of the nucleotide or oligonucleotides occurs. The chemistry of the reaction depends on the type of activated phosphorous compound.

Several methods for coupling nucleotides are known. The most common methods are via phosphoramidite and via H-phosphonate. In each of these cases the phosphor is in an activated state which allows coupling with the free hydroxyl group of the other part.

5 In phosphoramidite chemistry (Beaucage et al., *Tetrahedron*, 1992, 48, 2223-2311; Beaucage and Caruthers in unit 3.3 of *Current Protocols in Nucleic Acid Chemistry*, Wiley) a nucleoside or oligonucleotide-3'-O-phosphoramidite where the P(III) phosphorus is substituted with a dialkylamine (phosphite activating group) and a phosphorus protecting group (including but not limited to 2-cyanoethyl, methyl) is reacted with 5'-hydroxyl nucleoside or oligonucleotide in presence of an activator to create a phosphite triester internucleosidic linkage.

10 In H-phosphonate chemistry (Froehler, *Methods in Molecular Biology. Protocols for oligonucleotides and analogs*, Humana Press, 1993, 63-80; Strömberg and Stawinski, in unit 3.4 of *Current Protocols in Nucleic Acid Chemistry*, Wiley) a nucleoside or oligonucleotide-3'-O-H-phosphonate is reacted with a 5'-hydroxyl nucleoside or oligonucleotide in presence of an activator to create a H-phosphonate diester internucleosidic linkage.

15 Suitable activators for the coupling step in phosphoramidite chemistry include, but are not limited to a solid support bearing a pyridinium salt, for example a solid support covalently linked to pyridine e.g. poly(vinyl)-pyridinium or the pyridinium is a counter ion of a cation exchange solid support. The cation exchange support can be a strong or a weak exchanger, for example a sulfonic acid or a carboxylic acid. The pyridinium salt can also be a substituted pyridinium salt, for example dichloropyridinium. It can further be a solid support bearing an optionally substituted azole (imidazole, triazole, tetrazole), or is the salt of a weak base anion exchange resin with a strong acid, or a weak cation exchange resin (carboxylic) in its protonated form (see US patent 5,574,146), or a solid support bearing an optionally substituted phenol (see W. Dabkowski and al., *Tet Lett*, 2000, 41, 7535-7539).

20 30 The use of imidazole is less preferred.

25 For the H-phosphonate method the suitable activators include, but are not limited to solid supports bearing a carboxylic acid chloride, sulfonic acid chloride, a chloroformate, a chlorosulfite or a phosphorochloridate or the respective Br-compounds. Further compounds are disclosed in WO 01/64702 A1, page 6, line 35 36 to page 8, line 5, incorporated by reference and CB Reese and Q Song, Nu-

cleic Acid Res., 1999, 27, 963-971.

Step c) Capping and Oxidizing

Capping is understood as a reaction wherein a reagent reacts with remaining protected compounds of step a). As the capping agent is preferably solid supported, the 3'-protected compound can be removed together with the solid supported capping agent.

For the capping step suitable reagents suitable capping agents include, but are not limited to activated acids for example carboxylic acid, chloride or sulfonic acid chloride, carboxylic acid bromide, azolide, substituted azolide, anhydride or chloroformate or phosphorochloridate, or a solid supported phosphoramidate, or a solid supported H-phosphonate monoester. The acid group is preferably an acid group covalently bound to a solid support. Commercially available cationic exchanger resins can be used as a starting material for synthesizing the solid supported carboxylic acids or sulfonic acids.

The oxidizing reaction is used to oxidize the P(III)-internucleotide bond to a P(V)-internucleotide bond. Capping can be performed before oxidizing and vice versa. Depending on the reagents capping and oxidizing may also be combined in one step.

In case of H-phosphonate chemistry, the oxidizing step is preferably done in every second or third cycle or at the end of synthesis only. In phosphoamidite chemistry removal of the excess of 5' nucleoside oligonucleotide can be facilitated by a hydrolysis step, for example with water.

For the oxidizing step the oxidizing reagent can be any oxidizing reagent used for prior art solid phases, preferably in the form of solid supported agent, either covalently bound or bound by ionic forces. Suitable reagents are solid supported periodates, permanganates, osmium tetroxides, dichromates, hydroperoxides, substituted alkylamine oxides, percarboxylic acid and persulfonic acid.

These compounds are negatively charged, therefore they can be solid supported by a suitable ion exchanger for example an ion exchanger bearing ammonium groups. These substances could be bound to solid support consisting for example of an amino, alkyl amino, dialkyl amino or trialkyl amino anion exchanger.

In oligonucleotides synthesis for investigational purposes and especially for antisense therapeutics phosphorthioate analogs are used. In this case the oxidizing is a sulfurization. As a solid supported oxidizing reagent a solid supported sulfu-

5 rization reagent is used, for example a solid supported tetrathionate, a solid supported alkyl or aryl sulfonyl disulfide, a solid supported optionally substituted dibenzoyl tetrasulfide, a solid supported bis(alkyloxythiocarbonyl)tetrasulfide, a solid supported optionally substituted phenylacetyl disulfide, a solid supported N- [(alkyl or aryl)sulfanyl] alkyl or aryl substituted succinimide and a solid supported (2-pyridinyl)dithio) alkyl or aryl.

Very preferred is a solid supported cyanoethylthiosulfate (NC-CH₂-CH₂S-SO₃⁻), available according to the procedure in US 3,506,676 or a solid supported tetrathionate.

10 **Step d) Deprotection**

15 Suitable 5'-protection group include, but are not limited to trityl groups, preferably a dimethoxytrityl group (DMTr) or a monomethoxytrityl group (MMTr). These protection groups are used in conventional prior art solid phase oligonucleotides synthesis. Other suitable 5'-protection groups include, but are not limited to 20 tert-butyl dimethylsilyl (TBDMS), levulinyl, benzoyle, fluorenemethoxycarbonyl (FMOC), the 9-phenylthioxanthen-9-yl (S-pixyl).

In the second embodiment, in step d) the 3'-protection group is removed. Suitable 3'-protection groups include, but are not limited to 3'-O-*tert* butyl dimethyl silyl (TBDMS), 3'-O-acetate, 3'-O-levulinyl groups. They can be removed by a solid-supported ammonium fluoride, solid-supported ammonium hydroxide or solid-supported hydrazine.

25 In step d) of the first embodiment, the 5'-protection group is removed. Thereafter the oligonucleotides can either be used or the oligonucleotide corresponds to the 3'-protected compound of step a) to repeat the cycle.

30 The use of solid supported reagents for the removal of the DMTr-protection group for a completely synthesized oligonucleotide has already been reported in US 5,808,042. The content of this document is incorporated by reference. Surprisingly the methods disclosed in US 5,808,042 can also be applied in a solution phase synthesis as described in the present application.

35 Suitable reagents are also disclosed in synthetic communications 24 (17) 1994, 2323-2428.

In step d) of the second embodiment, the 3'-protection group is removed. Thereafter the oligonucleotides can either be used or the oligonucleotide corresponds to the 5'-protected compound of step a) to repeat the cycle.

Step e): Repetition

In most cases the methods will be repeated at least once. When starting from monomeric oligonucleotides the method of the present invention will result in a dimer. Repeating the method of the present invention will elongate the dimer to 5 a trimer. By repeating the method of the invention several times n-mers can be synthesized.

As the yield of a synthesis is not 100%, the overall yield of correct oligonucleotides decreases with the number of cycles. Depending on the yield of a single 10 cycle, oligonucleotides can be synthesized of at least up to 100 nucleotides in sufficient yield, but longer oligonucleotides are also possible.

For most cases oligonucleotides having that size will not be needed. An antisense therapy oligonucleotides are normally in the range of 8-36 nucleotides, more preferably 12-30, most commonly in the range of the 16-26 nucleotides.

In contrast to prior art, convergent synthesis strategies are fully compatible with 15 the synthesis method of the present invention. Convergent synthesis methods are methods wherein small oligonucleotides are synthesized first and the small oligonucleotides are then combined for synthesizing larger blocks. By this method the number of coupling reactions can be significantly reduced. Thereby the overall yield of the oligonucleotide is increased.

20 In prior art, each synthesis of a small oligonucleotide had to start from the solid support bound nucleic acid which was rather expensive. Therefore convergent synthesis strategies have not found much application in oligonucleotide synthesis.

Convergent synthesis has the further advantage, that the reaction product is 25 essentially free of (n-1)mers. In prior art synthesis, the purification of oligonucleotides with a length of n from oligonucleotides with a length of n-1 is the most difficult in purification of the oligonucleotide. By convergent synthesis, these (n-1)mers are nearly avoided, because larger fragments are combined.

In a preferred embodiment, the method of the present invention uses dimers or 30 trimers as the compounds in step a) and/or b).

During the synthesis cycles, reagents are mostly added in a solid supported form. These solid supported reagents are preferably removed after reaction or after each reaction step. Depending on the type of reagent it is in some cases possible to remove two or more of the solid supported reagents together.

- 10 -

In a preferred embodiment, coupling and at least final oxidizing steps are done by solid supported reagents.

As the synthesis is intended for the production of large amounts of oligonucleotides it is preferred that the solid supported reagent is recycled. This recycling is 5 obviously easier if the solid supported reagents are removed separately after each reaction.

The solid supported reagents can be removed by methods like filtration or centrifugation. Because of the ease of handling, filtration is the preferred way of removing the solid supported reagents.

10 A very preferred reagent for the sulfurization is a solid supported anion exchange resin in complex with a tetrathionate having the formula S_4O_6 , preferably a quaternary ammonium resin bearing tetrathionate as counter ion.

Purification

15 After the final synthesis cycle, it will in most cases be necessary to make one or more additional purification steps. Such purification steps for crude oligonucleotide synthesis products are known in prior art solid phase synthesis.

It is necessary to remove the remaining protection groups especially from the heterocyclic bases and optionally remaining protecting groups on the sugar or phosphorous backbone.

20 In a preferred embodiment, in case of the use of MMT or DMT as a protection group, the oligonucleotide is purified by binding to an ion exchanger and the protection group is removed while the oligonucleotide is bound to the exchanger. After removal of the protection groups, the oligonucleotide is released from the ion exchanger.

25 The invention will be further exemplified with the following examples.

Example 1

Synthesis of the dimer 5'-O-DMTr-T-T-3'-O-TBDMS cyanoethyl phosphite tri-ester.

30 **Coupling procedure** of 5'-O-DMTr-T-3'-cyanoethyl phosphoramidite with 5'-OH-T-3'-O-TBDMS using the DOWEX 50W X8 pyridinium form.

Analytical scale.

5'-OH-T-3'-O-TBDMS (11 mg, 32.5 mmol) and 5'-O-DMTr-T-3'-cyanoethyl

phosphoramidite (41 mg, 55.25 mmol, 1.7 eq) are dissolved in anhydrous acetonitrile (550 ml). The solution is transferred under argon in a NMR tube containing the DOWEX 50W X8 pyridinium form (100 mg, 0.30 mmol pyrH⁺, 9.2 eq). The reaction is followed by ³¹P NMR. Before the NMR experiment 5 deuterated acetonitrile (50 ml) is added. The yield is determined by ³¹P NMR. After 3 h the desired dimer T-T phosphite triester is obtained with 100% of yield compared to 5'-OH-T-3'-O-TBDMS. The crude is a mixture of 5'-O-DMTr-T-3'-cyanoethyl phosphoramidite (³¹P NMR (CD₃CN) δ 149.14, 149.07, 14.7%), 5'-O-DMTr-T-T-3'-O-TBDMS cyanoethyl phosphite triester (δ 140.53, 70.2%), 10 5'-O-DMTr-T-3'-cyanoethyl hydrogenophosphonate (δ 8.74, 15.1%).

Example 2

Synthesis of the dimer 5'-O-DMTr-T-T-3'-O-TBDMS cyanoethyl phosphite triester.

15 **Coupling procedure** of 5'-O-DMTr-T-3'-cyanoethyl phosphoramidite with 5'-OH-T-3'-O-TBDMS using the poly(4-vinylpyridinium *p*-toluenesulfonate) (Aldrich).

Analytical scale.

20 5'-OH-T-3'-O-TBDMS (11 mg, 32.5 mmol) and 5'-O-DMTr-T-3'-cyanoethyl phosphoramidite (41 mg, 55.25 mmol, 1.7 eq) are dissolved in anhydrous acetonitrile (550 ml). The solution is transferred under argon in a NMR tube containing the poly(4-vinylpyridinium *p*-toluenesulfonate) (100 mg, 0.33 mmol tos⁻, 10.3 eq). The reaction is followed by ³¹P NMR. Before the NMR experiment 25 deuterated acetonitrile (50 ml) is added. The yield is determined by ³¹P NMR. After 1 h 45 the desired dimer T-T phosphite triester is obtained with 82% of yield compared to 5'-OH-T-3'-O-TBDMS. The crude is a mixture of 5'-O-DMTr-T-T-3'-O-TBDMS cyanoethyl phosphite triester (³¹P NMR (CD₃CN) δ 140.54, 48.2%), 5'-O-DMTr-T-3'-cyanoethyl hydrogenophosphonate (δ 8.77, 51.8%).

Example 3

30 *Synthesis of the dimer 5'-OH-T-T-3'-O-TBDMS cyanoethyl phosphorothioate triester.*

Coupling procedure of 5'-O-DMTr-T-3'-cyanoethyl phosphoramidite with 5'-OH-T-3'-O-TBDMS using the DOWEX 50W X8 pyridinium form.

A solution of 5'-OH-T-3'-O-TBDMS (124 mg, 0.35 mmol) and 5'-O-DMTr-T-3'-

cyanoethyl phosphoramidite (441 mg, 0.59 mmol, 1.7 eq) in anhydrous acetonitrile (6 ml) is added to DOWEX 50W X8 pyridinium form (1 g, 3 mmol pyrH⁺, 9.5 eq). The resulting mixture is shaken for 4 h 45. The reaction is followed by ³¹P NMR and the yield is also determined by ³¹P NMR. The desired dimer 5'-O-
5 DMTr-T-T-3'-O-TBDMS cyanoethyl phosphite triester is obtained with 100% of
yield compared to 5'-OH-T-3'-O-TBDMS. The crude is a mixture of 5'-O-DMTr-
T-3'-cyanoethyl phosphoramidite (³¹P NMR (CD₃CN) δ 149.17, 149.10, 5.4%),
5'-O-DMTr-T-T-3'-O-TBDMS cyanoethyl phosphite triester (δ 140.57, 140.54,
68.3%), 5'-O-DMTr-T-3'-cyanoethyl hydrogenophosphonate (δ 8.75, 8.71,
10 26.3%).

Sulfurization: The DOWEX 50W X8 resin is filtered off and the resulting solution is added to AMBERLYST A26 tetrathionate form (1.44 g, 2.44 mmol S₄O₆²⁻, 7 eq.). The reaction is followed by ³¹P NMR and the yield is also determined by ³¹P NMR. After 20 h the desired dimer 5'-O-DMTr-T-T-3'-O-TBDMS cyanoethyl phosphorothioate triester is obtained with 97% of yield. The crude is a mixture of 5'-O-DMTr-T-3'- cyanoethyl thiophosphoramidate (³¹P NMR (CD₃CN) δ 71.16, 4.0%), 5'-O-DMTr-T-T-3'-O-TBDMS cyanoethyl phosphorothioate triester (δ 68.28, 68.23, 69.5%), 5'-O-DMTr-T-3'-cyanoethyl hydrogenophosphonate (δ 8.75, 8.71, 26.5%). MALDI-TOF MS (negative mode, trihydroxyacetophenone as matrix) ammonia treatment of an aliquot gives 5'-OH-T-T- 3'-O-TBDMS phosphorothioate diester: [M-H]⁻ m/z_{exp} = 978.12, m/z_{calc} = 977.13.

Detritylation: The AMBERLYST A26 is filtered off and the solvent are evaporated. The crude is dissolved in 4ml of CH₂Cl₂/CH₃OH (7/3) and cooled in an ice bath. To this solution is added 1 ml of a solution of benzene sulfonic acid 25 10% in CH₂Cl₂/CH₃OH (7/3). The solution is stirred 15 min at 0°C. The reaction is washed with 10 ml of a saturated solution of NaHCO₃, the organic layer is separated, dried (Na₂SO₄), evaporated, and purified on a silica gel column. The desired dimer T-T is eluted with CH₂Cl₂/CH₃OH (95/5). The appropriate fractions are collected and evaporated to give 230 mg of a white foam in a yield of
30 83% compared to 5'-OH-T-3'-O-TBDMS. ³¹P NMR (CD₃CN) δ 68.29, 68.19. MALDI-TOF MS (positive mode, trihydroxyacetophenone as matrix) [M+H]⁺ m/z_{exp} = 730.46, m/z_{calc} = 730.82. The spectrophotometric purity (97%) is determined by HPLC at 260 nm.

Example 4

35 *Synthesis of the trimer 5'-OH-T-T-T-3'-O-TBDMS cyanoethyl phosphorothioate triester.*

Coupling procedure of 5'-O-DMTr-T-3'-cyanoethyl phosphoramidite with the dimer 5'-OH-T-T-3'-O-TBDMS cyanoethyl phosphorothioate triester using the DOWEX 50W X8 pyridinium form.

A solution of 5'-OH-T-T-3'-O-TBDMS cyanoethyl phosphorothioate triester

5 (230 mg, 0.31 mmol) and 5'-O-DMTr-T-3'-cyanoethyl phosphoramidite (399 mg, 0.54 mmol, 1.7 eq) in anhydrous acetonitrile (8 ml) is added to DOWEX 50W X8 pyridinium form (1 g, 3 mmol pyrH⁺, 9.5 eq). The resulting mixture is shaken for 5 h. The reaction is followed by ³¹P NMR and the yield is also determined by ³¹P NMR. The desired trimer 5'-O-DMTr-T-T-T-3'-O-TBDMS cyanoethyl phosphite triester is obtained with 100% of yield compared to the dimer 10 5'-OH-T-T-3'-O-TBDMS cyanoethyl phosphorothioate triester. The crude is a mixture of 5'-O-DMTr-T-3'-cyanoethyl phosphoramidite (³¹P NMR (CD₃CN) δ 149.16, 149.10, 17.7%), 5'-O-DMTr-T-T-T-3'-O-TBDMS cyanoethyl phosphite triester (δ 140.85, 140.68, 140.37, 140.30, d 68.07, 68.02, 68.3%), 5'-O-15 DMTr-T-3'-cyanoethyl hydrogenophosphonate (δ 8.7, 8.68, 14%).

Sulfurization: The DOWEX 50W X8 pyridinium form is filtered off and the resulting solution is added to AMBERLYST A26 tetrathionate form (1.3 g, 2.44 mmol S₄O₆²⁻, 7 eq.). The reaction is followed by ³¹P NMR and the yield is also determined by ³¹P NMR. After 45 h the desired trimer 5'-O-DMTr-T-T-T-3'-O-

20 TBDMS cyanoethyl phosphorothioate triester is obtained with 100% of yield. MALDI-TOF MS (negative mode, trihydroxyacetophenone as matrix) [M-H]⁻ m/z_{exp} = 1297.89, m/z_{calc} = 1296.38 after 30 min of ammonia treatment to remove the cyanoethyl protecting group. The crude is a mixture of 5'-O-DMTr-T-3'- cyanoethyl thiophosphoramidate (³¹P NMR (CD₃CN) d 72.04, 71.17, 14.0%), 5'-O-DMTr-T-T-T-3'-O-TBDMS cyanoethyl phosphorothioate triester (d 68.17, 68.12, 68.07, 67.96, 67.80, 67.58, 73.8%), 5'-O-DMTr-T-3'- cyanoethyl hydrogenophosphonate (d 8.76, 8.71, 12.2%).

Detritylation: The AMBERLYST A26 is filtered off and the solvent are evaporated. The crude is dissolved in 4ml of CH₂Cl₂/CH₃OH (7/3) and cooled in an 30 ice bath. To this solution is added 1 ml of a solution of benzene sulfonic acid 10% in CH₂Cl₂/CH₃OH (7/3). The solution is stirred 45 min at 0°C. The reaction is washed with 10 ml of a saturated solution of NaHCO₃, the organic layer is separated, dried (Na₂SO₄), evaporated, and purified on a silica gel column. The desired trimer T-T-T is eluted with CH₂Cl₂/CH₃OH (95/5). The appropriate fractions are collected and evaporated to give 221 mg of a white foam in a 35 yield of 63% compared to the dimer 5'-OH-T-T-3'-O-TBDMS cyanoethyl phos-

phorothioate triester. ^{31}P NMR (CD_3CN) δ 68.53, 68.38, 68.34, 67.74, 67.54. MALDI-TOF MS (positive mode, trihydroxyacetophenone as matrix) $[\text{M}+\text{H}]^+$ $m/z_{\text{exp}} = 1103.91$, $m/z_{\text{calc}} = 1104.15$. The spectrophotometric purity (93%) is determined by HPLC at 260 nm.

5 Example 5

Synthesis of the dimer 5'-OH-T-dA^{Bz}-3'-O-TBDMS cyanoethyl phosphorothioate triester.

Coupling procedure of 5'-O-DMTr-T-3'-phosphoramidite with 5'-OH-dA^{Bz}-3'-O-TBDMS using the poly(4-vinylpyridinium *p*-toluenesulfonate) (Aldrich).

10 A solution of 5'-OH-dA^{Bz}-3'-O-TBDMS (176 mg, 0.38 mmol) and 5'-O-DMTr-T-3'-cyanoethyl phosphoramidite (560 mg, 0.75 mmol, 2 eq) in anhydrous acetonitrile (6 ml) is added to poly(4-vinylpyridinium *p*-toluenesulfonate) (1.15 g, 3.84 mmol tos⁻, 10.2 eq). The resulting mixture is shaken for 4 h 30 min. The reaction is followed by ^{31}P NMR and the yield is also determined by ^{31}P NMR.

15 The desired dimer 5'-O-DMTr-T-dA^{Bz}-3'-O-TBDMS cyanoethyl phosphite triester is obtained with 100 % of yield compared to the 5'-OH-dA^{Bz}-3'-O-TBDMS. The crude is a mixture of 5'-O-DMTr-T-3'-cyanoethyl phosphoramidite (^{31}P NMR (CD_3CN) δ 149.10, 149.05, 12.3%), 5'-O-DMTr-T-A^{Bz}-3'-O-TBDMS cyanoethyl phosphite triester (δ 140.52, 140.37, 50%), 5'-O-DMTr-T-3'-cyanoethyl hydrogenophosphonate (δ 8.72, 8.69, 37.7%).

20

Sulfurization: The poly(4-vinylpyridinium *p*-toluenesulfonate) is filtered off and the resulting solution is added to AMBERLYST A26 tetrathionate form (1.55 g, 2.63 mmol $\text{S}_4\text{O}_6^{2-}$, 7 eq.). The reaction is followed by ^{31}P NMR. The reaction mixture is shaken for 24 h 30. The desired dimer 5'-O-DMTr-T-dA^{Bz}-3'-O-TBDMS cyanoethyl phosphorothioate triester is isolated after filtration of the resin, evaporation of the solvent, and column chromatography (silica gel; CH_2Cl_2 / MeOH (50/1)). Yield: 325 mg, 0.28 mmol, 76%. ^{31}P NMR (CD_3CN) δ 68.34, 68.15. MALDI-TOF MS (positive mode, trihydroxyacetophenone as matrix) $[\text{M}+\text{H}]^+$ $m/z_{\text{exp}} = 1144.22$, $m/z_{\text{calc}} = 1146.32$.

30 **Detritylation:** The 5'-O-DMTr-T-dA^{Bz}-3'-O-TBDMS cyanoethyl phosphorothioate triester is dissolved in 10 ml of CH_2Cl_2 / CH_3OH (7/3) and cooled in an ice bath. To this solution is added 1 ml of a solution of benzene sulfonic acid 10% in CH_2Cl_2 / CH_3OH (7/3). The solution is stirred 35 min at 0°C. The reaction is washed with 20 ml of a saturated solution of NaHCO_3 , the organic layer is separated, dried (Na_2SO_4), evaporated, and purified on a silica gel

35

column. The desired dimer T-dA^{Bz} is eluted with CH₂Cl₂/CH₃OH (95/5). The appropriate fractions are collected and evaporated to give a white foam. Yield: 223 mg, 0.26 mmol, 71%. ³¹P NMR (CD₃CN) δ 68.06, 67.89. MALDI-TOF MS (positive mode, trihydroxyacetophenone as matrix) [M-H]⁺ m/z_{exp} = 842.18, m/z_{calc} = 843.95; (negative mode, trihydroxyacetophenone as matrix) ammonia treatment of an aliquot gives 5'-OH-T-dA- 3'-O-TBDMS phosphorothioate diester: [M-H]⁻ m/z_{exp} = 685.38, m/z_{calc} = 684.77.

Example 6

10 *Synthesis of the trimer 5'-O-DMTr-dA^{Bz}-T-dA^{Bz}-3'-O-TBDMS cyanoethyl phosphorothioate triester.*

Coupling procedure of 5'-O-DMTr-dA^{Bz}-3'-cyanoethyl phosphoramidite with the dimer 5'-OH-T-dA^{Bz}-3'-O-TBDMS phosphorothioate triester using the poly(4-vinylpyridinium p-toluenesulfonate) (Aldrich).

15 A solution of the dimer 5'-OH-T-dA^{Bz}-3'-O-TBDMS phosphorothioate triester (223 mg, 0.26 mmol) and 5'-O-DMTr-dA^{Bz}-3'-cyanoethyl phosphoramidite (432 mg, 0.50 mmol, 1.9 eq) in anhydrous acetonitrile (20 ml) is added to poly(4-vinylpyridinium p-toluenesulfonate) (0.8 g, 2.7 mmol tos⁻, 10.3 eq). The resulting mixture is shaken for 6 h 30. The reaction is followed by ³¹P NMR and the yield is also determined by ³¹P NMR. The desired trimer 5'-O-DMTr-dA^{Bz}-T-dA^{Bz}-3'-O-TBDMS cyanoethyl phosphite triester is obtained with 62% of yield compared to the dimer 5'-OH-T-dA^{Bz}-3'-O-TBDMS phosphorothioate triester. The crude is a mixture of 5'-O-DMTr-dA^{Bz}-3'-cyanoethyl phosphoramidite (³¹P NMR (CD₃CN) d 149.14, 8.4%), 5'-O-DMTr-dA^{Bz}-T-dA^{Bz}-3'-O-TBDMS cyanoethyl phosphite triester δ(140.90, 140.77, 67.85, 67.79, 43.3%), 5'-OH-T-dA^{Bz}-3'-O-TBDMS phosphorothioate triester (δ 68.03, 67.89, 13.4%), 5'-O-DMTr-dA^{Bz}-3'-cyanoethyl hydrogenophosphonate (δ 8.71, 8.66, 34.9%).

20 **Sulfurization:** The poly(4-vinylpyridinium p-toluenesulfonate) is filtered off and the resulting solution is added to AMBERLYST A26 tetrathionate form (0.78 g, 1.33 mmol S₄O₆²⁻, 5 eq.). The reaction is followed by ³¹P NMR and the yield is also determined by ³¹P NMR. After 14 h 30 the desired trimer 5'-O-DMTr-dA^{Bz}-T-dA^{Bz}-3'-O-TBDMS cyanoethyl phosphorothioate triester is obtained with 100% of yield. The crude is a mixture of 5'-O-DMTr-dA^{Bz}-3'- cyanoethyl thiophosphoramidate (³¹P NMR (CD₃CN) d 71.88, 71.21, 10%), 5'-O-DMTr-dA^{Bz}-T-dA^{Bz}-3'-O-TBDMS cyanoethyl phosphorothioate triester (25.9%) and 5'-OH-T-dA^{Bz}-3'-O-TBDMS cyanoethyl phosphorothioate triester (16.2%).

(δ 68.08, 68.05, 67.93, 67.89, 67.85, 67.79, 67.57), 5'-O-DMTr-T-3'-cyanoethyl phosphorothioate diester (δ 57.38, 4.8%), 5'-O-DMTr-dA^{Bz}-3'-cyanoethyl hydrogenophosphonate (δ 8.75, 8.70, 43.11%). MALDI-TOF MS (positive mode, trihydroxyacetophenone as matrix) $[M+H]^+$ $m/z_{exp} = 1631.68$, 5 $m/z_{calc} = 1632.77$; (negative mode, trihydroxyacetophenone as matrix) ammonia treatment of an aliquot gives 5'-OH-T-dA- 3'-O-TBDMS phosphorothioate diester: $[M-H]^-$ $m/z_{exp} = 1316.45$, $m/z_{calc} = 1316.43$.

Example 7

10 *Synthesis of the dimer 5'-O-DMTr-dC^{Bz}-T-3'-O-Lev cyanoethyl phosphite triester.*

Coupling procedure of 5'-O-DMTr-dC^{Bz}-3'-cyanoethyl phosphoramidite with 5'-OH-T-3'-O-Lev using the DOWEX 50W X8 pyridinium form.

Analytical scale.

15 5'-OH-T-3'-O-Lev (20 mg, 58.9 mmol) and 5'-O-DMTr-dC^{Bz}-3'-cyanoethyl phosphoramidite (83.4 mg, 100 mmol, 1.7 eq) are dissolved in anhydrous acetonitrile (550 ml). The solution is transferred under argon in a NMR tube containing the DOWEX 50W X8 pyridinium form (181 mg, 0.54 mmol pyrH⁺, 9.2 eq). The reaction is followed by ³¹P NMR. Before the NMR experiment deuterated acetonitrile (50 ml) is added. The yield is determined by ³¹P NMR. 20 After 6 h the desired dimer T-dC^{Bz} phosphite triester is obtained with 100% of yield compared to 5'-OH-T-3'-O-Lev. The crude is a mixture of 5'-O-DMTr-dC^{Bz}-3'-cyanoethyl phosphoramidite (³¹P NMR (CD₃CN) δ 149.36, 149.32, 11%), 5'-O-DMTr-T-dC^{Bz}-3'-O-TBDMS cyanoethyl phosphite triester (δ 140.52, 140.39, 70%), 5'-O-DMTr- dC^{Bz} -3'-cyanoethyl hydrogenophosphonate 25 (δ 8.90, 8.58, 19%).

Example 8

Synthesis of the dimer 5'-OH-dC^{Bz}-T-3'-O-Lev cyanoethyl phosphorothioate triester.

30 **Coupling procedure** of 5'-O-DMTr-dC^{Bz}-3'-cyanoethyl phosphoramidite with 5'-OH-T-3'-O-Lev using the DOWEX 50W X8 pyridinium form.

A solution of 5'-OH-T-3'-O-Lev (119 mg, 0.35 mmol) and 5'-O-DMTr-dC^{Bz}-3'-cyanoethyl phosphoramidite (496 mg, 0.60 mmol, 1.7 eq) in anhydrous acetonitrile (10 ml) is added to DOWEX 50W X8 pyridinium form (1.1 g, 3.3 mmol pyrH⁺, 9.4 eq). The resulting mixture is shaken for 5 h 30 min. The reaction is

followed by ^{31}P NMR and the yield is also determined by ^{31}P NMR. The desired dimer 5'-O-DMTr-dC^{Bz}-T-3'-O-Lev cyanoethyl phosphite triester is obtained with 100% of yield compared to 5'-OH-T-3'-O-Lev. The crude is a mixture of 5'-O-DMTr-T-dC^{Bz}-3'-O-Lev cyanoethyl phosphite triester (^{31}P NMR (CD₃CN) δ 5 140.59, 140.45, 64%), 5'-O-DMTr-dC^{Bz}-3'-cyanoethyl hydrogenophosphonate (δ 8.68, 8.66, 36%).

Sulfurization: The DOWEX 50W X8 resin is filtered off and the resulting solution is added to AMBERLYST A26 tetrathionate form (1.44 g, 2.44 mmol S₄O₆²⁻, 7 eq.). The reaction is followed by ^{31}P NMR. The reaction mixture is shaken for 10 16 h. The desired dimer 5'-O-DMTr-dC^{Bz}-T-3'-O-Lev cyanoethyl phosphorothioate triester is isolated after filtration of the resin, evaporation of the solvent and column chromatography (silica gel; CH₂Cl₂ / MeOH (97/3)). The crude is a mixture of 5'-O-DMTr-T-dC^{Bz}-3'-O-Lev cyanoethyl phosphorothioate triester (^{31}P NMR (CD₃CN) δ 68.05, 67.89, 83.7%), 5'-O-DMTr-dC^{Bz}-3'-cyanoethyl hydrogenophosphonate (δ 8.63, 16.3%). The spectrophotometric purity determined by HPLC at 260 nm is 80%.

Detrytilation of the dimer 5'-O-DMTr-dC^{Bz}-T-3'-O-Lev cyanoethyl phosphorothioate triester with the DOWEX 50 W X8 H⁺ form (Aldrich).

To the mixture of the dimer 5'-O-DMTr-dC^{Bz}-T-3'-O-Lev cyanoethyl phosphorothioate triester (121 mmol estimated) and 5'-O-DMTr-T-3'-cyanoethyl hydrogenophosphonate diester (44 mmol estimated) in solution in 10 ml of CH₂Cl₂/MeOH (7/3) is added the DOWEX 50 W X8 H⁺ form (1.4 g, 7 mmol H⁺, 58 eq / dimer). The reaction is followed by reverse phase HPLC. After 15 min the detritylation is complete. The resin is filtered off and the solvents are 20 evaporated. The desired dimer 5'-OH-dC^{Bz}-T-3'-O-Lev cyanoethyl phosphorothioate triester is purified by precipitation from CH₂Cl₂/MeOH (9/1) in diethylether. ^{31}P NMR (CD₃OD) δ 68.24, 67.90, MALDI-TOF MS (positive mode, trihydroxyacetophenone as matrix) [M-H]⁺ m/z_{exp} = 803.11 m/z_{calc} = 803.76. The spectrophotometric purity (97 %) is determined by HPLC at 260 nm.

30 **Example 9**

Synthesis of the dimer 5'-OH-T-T-3'-O-Lev cyanoethyl phosphorothioate triester.

Coupling procedure of 5'-O-DMTr-T-3'-cyanoethyl phosphoramidite with 5'-OH-T-3'-O-Lev using the DOWEX 50W X8 pyridinium form.

35 A solution of 5'-OH-T-3'-O-Lev (100 mg, 0.29 mmol) and 5'-O-DMTr-T-3'-

cyanoethyl phosphoramidite (547 mg, 0.73 mmol, 2.5 eq) in anhydrous acetonitrile (10 ml) is added to DOWEX 50W X8 pyridinium form (0.9 g, 2.7 mmol pyrH⁺, 9.3 eq). The resulting mixture is shaken for 10 h. The reaction is followed by ³¹P NMR and by reverse phase HPLC. The excess of 5'-O-DMTr-T-3'-

5 cyanoethyl phosphoramidite is hydrolysed with 500 ml of water. The desired dimer 5'-O-DMTr-T-T-3'-O-Lev cyanoethyl phosphite triester is obtained with 100% of yield compared to 5'-OH-T-3'-O-Lev. The crude is a mixture of 5'-O-DMTr-T-T-3'-O-Lev cyanoethyl phosphite triester (HPLC % Area = 55%) and 5'-O-DMTr-T-3'-cyanoethyl hydrogenophosphonate (HPLC % Area = 45%) .

10 **Sulfurization:** The DOWEX 50W X8 resin is filtered off and the resulting solution is added to AMBERLYST A26 tetrathionate form (0.8 g, 1.5 mmol S₄O₆²⁻, 5 eq.). The reaction is followed by ³¹P NMR and by reverse phase HPLC. After 15 h the desired dimer 5'-O-DMTr-T-T-3'-O-Lev cyanoethyl phosphorothioate triester is obtained with 100% of yield. The crude is a mixture of 5'-O-DMTr-T-15 T-3'-O-Lev cyanoethyl phosphorothioate triester (³¹P NMR d 68.04, HPLC % Area = 57%), 5'-O-DMTr-T-3'-cyanoethyl hydrogenophosphonate (d 8.77, HPLC % Area = 43%).

Dettrytiation of the dimer 5'-O-DMTr-T-T-3'-O-Lev cyanoethyl phosphorothioate triester with the DOWEX 50 W X8 H⁺ form (Aldrich).

20 The AMBERLYST A26 resin is filtered off and the solvents are evaporated. To the mixture of the dimer 5'-O-DMTr-T-T-3'-O-Lev cyanoethyl phosphorothioate triester (0.29 mmol estimated) and 5'-O-DMTr-T-3'-cyanoethyl hydrogenophosphonate (0.22 mmol estimated) in solution in 20 ml of CH₂Cl₂/MeOH (7/3) is added the DOWEX 50 W X8 H⁺ form (3.7 g, 18.5 mmol H⁺, 64 eq / dimer).

25 The reaction is followed by reverse phase HPLC. After 30 min the dettrytiation of the dimer is complete. The resin is filtered off and the solvents are evaporated. The desired dimer 5'-OH-T-T-3'-O-Lev cyanoethyl phosphorothioate triester is purified by precipitation from CH₂Cl₂/MeOH (9/1) in diethylether. ³¹P NMR (CD₃CN) d 67.88, 67.73. MALDI-TOF MS (positive mode, trihydroxyacetophenone as matrix) [M-H]⁺ m/z_{exp} = 713.79 m/z_{calc} = 714.66. The purity (95%) is determined by HPLC.

Example 10

Synthesis of dimer 5'-O-DMTr-dA^{Bz}-dA^{Bz}-3'-O-TBDMS cyanoethyl phosphorothioate triester dimer.

35 **Coupling procedure** of 5'-O-DMTr-dA^{Bz}-3'-cyanoethyl-phosphoramidite with

5'-OH-dA^{Bz}-3'-O-TBDMS using the DOWEX 50W X8 pyridinium form:

5'-OH-dA^{Bz}-3'-O-TBDMS (100 mg, 0.21 mmol) and 5'-O-DMTr-dA^{Bz}-3'-cyanoethyl-phosphoramidite (311 mg, 0.36 mmol, 1.7 eq) are dissolved in anhydrous acetonitrile (15 ml). The solution is transferred under argon in a flask containing the DOWEX 50W X8 pyridinium form (655 mg, 1.97 mmol pyrH⁺, 9.2 eq) and is shaken for 4 h 30 min. The reaction is followed by ³¹P NMR. The yield is determined by ³¹P NMR. The desired dA-dA phosphite triester dimer is obtained with 92% of yield compared to the 5'-OH-dA^{Bz}-3'-O-TBDMS. The crude is a mixture of 5'-O-DMTr-dA^{Bz}-3'-cyanoethyl phosphoramidite (³¹P NMR (CD₃CN) δ 149.25, 149.13; 27.7%), 5'-O-DMTr-dA^{Bz}-dA^{Bz}-3'-O-TBDMS cyanoethyl phosphite triester (δ 140.75, 140.38; 53.9%), 5'-O-DMTr-dA^{Bz}-3'-cyanoethyl hydrogenophosphonate (δ 8.69, 8.64; 18.5%).

10 **Sulfurization:** To a solution of 5'-O-DMTr-dA^{Bz}-dA^{Bz}-3'-O-TBDMS phosphite triester dimer (0.2 mmol) in anhydrous acetonitrile is added AMBERLYST A26 15 tetrathionate form (5.4 eq., 1.14 mmol S₄O₆²⁻, 0.63 g). The reaction mixture is shaken for 20 h. The reaction is followed by ³¹P NMR. The yield is determined by ³¹P NMR. After filtration of the resins the desired dimer dA-dA phosphorothioate triester is obtained with 88% of yield compared to the 5'-OH-dA^{Bz}-3'-O-TBDMS. The crude is a mixture of 5'-O-DMTr-dA^{Bz}-3'-cyanoethyl 20 thiophosphoramidate (³¹P NMR (CD₃CN) δ 71.85, 71.22; 29.0%), 5'-O-DMTr-dA^{Bz}-dA^{Bz}-3'-O-TBDMS cyanoethyl phosphorothioate (δ 68.08, 68.01; 51.5%), 5'-O-DMTr-dA^{Bz}-3'-cyanoethyl hydrogenophosphonate (δ 8.66, 8.59; 19.5%).

Example 11

25 *Synthesis of the dimer 5'-OH-dC^{Bz}-dA^{Bz}-3'-O-TBDMS cyanoethyl phosphorothioate triester.*

Coupling procedure of 5'-O-DMTr-dC^{Bz}-3'-cyanoethyl-phosphoramidite with 5'-OH-dA^{Bz}-3'-O-TBDMS using the poly(4-vinylpyridinium *p*-toluenesulfonate) (Aldrich):

30 5'-OH-dA^{Bz}-3'-O-TBDMS adenosine (100 mg, 0.21 mmol) and 5'-O-DMTr-dC^{Bz}-3'-cyanoethyl-phosphoramidite (365 mg, 0.43 mmol, 2. eq) are dissolved in anhydrous acetonitrile (15 ml). The solution is transferred under argon in a flask containing the poly(4-vinylpyridinium *p*-toluenesulfonate) (655 mg, 2.17 mmol tos⁻, 10.2 eq) and is shaken for 5 h 50 min. The reaction is followed by ³¹P NMR. The yield is determined by ³¹P NMR. The desired dC-dA phosphite 35 triester dimer is obtained with 100% of yield compared to the 5'-OH-dA^{Bz}-3'-O-

TBDMS. The crude is a mixture of 5'-O-DMTr-dC^{Bz}-dA^{Bz}-3'-O-TBDMS cyanoethyl phosphite triester (³¹P NMR (CD₃CN) (δ 140.55, 140.49; 53.9%), 5'-O-DMTr-dC^{Bz}-3'-cyanoethyl hydrogenophosphonate (δ 8.67; 18.5%).

Sulfurization: To a solution of 5'-O-DMTr-dC^{Bz}-dA^{Bz}-3'-O-TBDMS cyanoethyl

5 phosphite triester dimer (0.21 mmol) in anhydrous dichloromethane is added AMBERLYST A26 tetrathionate form (0.63 g, 1.14 mmol S₄O₆²⁻, 5.3 eq.). The reaction mixture is shaken for 14 h 30 min. The reaction is followed by ³¹P NMR. The yield is determined by ³¹P NMR. After filtration of the resins the desired dC-dA phosphorothioate triester dimer is obtained with 100% of yield compared to the 5'-OH-dA^{Bz}-3'-O-TBDMS. The crude is a mixture of 5'-O-DMTr-dC^{Bz}-dA^{Bz}-3'-O-TBDMS cyanoethyl phosphorothioate (³¹P NMR (CD₃CN) (d 68.14, 68.07; 50.6%), 5'-O-DMTr-dC^{Bz}-3'-cyanoethyl hydrogenophosphonate (d 8.67; 49.4%). Purification is attempted on a silica gel column, which is treated with triethylamine. Chromatography leads to complete loss of 10 the cyanoethyl group. The dC^{Bz}-dA^{Bz} phosphorothioate dimer is eluted with CH₂Cl₂/CH₃OH (80/1). The appropriate fractions are collected and evaporated to give a colorless oil. Yield: 185 mg, 0.14 mmol, 68%; ³¹P NMR (CD₃CN) d 57.58, 57.45; MALDI-TOF MS (positive mode, trihydroxyacetophenone as 15 matrix) [M-DMTr+2H]⁺ m/z_{exp} = 879.42, m/z_{calc} = 878.97.

20 **Example 12**

Synthesis of the dimer 5'-OH-dA^{Bz}-dA^{Bz}-3'-O-TBDMS cyanoethyl phosphorothioate triester.

Coupling procedure of 5'-O-DMTr-dA^{Bz}-3'-cyanoethyl-phosphoramidite with 25 5'-OH-dA^{Bz}-3'-O-TBDMS using the poly(4-vinylpyridinium *p*-toluenesulfonate) (Aldrich):

5'-OH-dA^{Bz}-3'-O-TBDMS (102 mg, 0.22 mmol) and 5'-O-DMTr-dA^{Bz}-3'-cyanoethyl-phosphoramidite (381 mg, 0.44 mmol, 2.05 eq) are dissolved in anhydrous dichloromethane (15 ml). The solution is transferred under argon in a flask containing the poly(4-vinylpyridinium *p*-toluenesulfonate) (655 mg, 2.19 mmol tos⁻, 10.1 eq) and is shaken for 5 h 40 min. The reaction is followed by 30 ³¹P NMR. The yield is determined by ³¹P NMR. The desired dA-dA phosphite triester dimer is obtained with 100% of yield compared to the 5'-OH-dA^{Bz}-3'-O-TBDMS. The crude is a mixture of 5'-O-DMTr-dA^{Bz}-dA^{Bz}-3'-O-TBDMS cyanoethyl phosphite triester (³¹P NMR (CD₃CN) (d 140.77, 140.46; 66.9%), 5'-O-DMTr-dA^{Bz}-3'-cyanoethyl hydrogenophosphonate (d 8.50, 8.41; 33.1%). 35

Sulfurization: To a solution of 5'-O-DMTr-dA^{Bz}-dA^{Bz}-3'-O-TBDMS cyanoethyl phosphite triester dimer (0.22 mmol) in anhydrous dichloromethane is added AMBERLYST A26 tetrathionate form (0.87 g, 1.14 mmol S₄O₆²⁻, 5.4 eq.). The reaction mixture is shaken for 22 h. The reaction is followed by ³¹P NMR. The yield is determined by ³¹P NMR. After filtration of the resins the desired dA-dA phosphorothioate triester dimer is obtained with 100 % of yield compared to the 5'-OH-dA^{Bz}-3'-O-TBDMS. The crude is a mixture of 5'-O-DMTr-dA^{Bz}-dA^{Bz}-3'-O-TBDMS cyanoethyl phosphorothioate (³¹P NMR (CD₃CN) (d 68.17, 67.89; 62.3%), 5'-O-DMTr-dA^{Bz}-3'-cyanoethyl hydrogenophosphonate (δ 8.45, 8.35; 37.7%).

Detritylation: To a solution of 5'-O-DMTr-dA^{Bz}-dA^{Bz}-3'-O-TBDMS cyanoethyl phosphorothioate triester (0.22 mmol) in 10 ml CH₂Cl₂/CH₃OH (7/3) is added 0.63 ml (0.3 mmol, 1.4 eq.) of a solution of benzene sulfonic acid 10% in CH₂Cl₂/CH₃OH (7/3). The solution is stirred 45 min at 0°C. The reaction is washed with 10 ml of a saturated solution of NaHCO₃, the organic layer is separated, dried (Na₂SO₄), evaporated, and purified on a silica gel column. The desired dA-dA dimer is eluted with CH₂Cl₂/CH₃OH (33/1). The appropriate fractions are collected and evaporated to give a colorless oil. Yield: 73 mg, 76 mmol, 35%; ³¹P NMR (CD₃CN) δ 67.80, 67.71; MALDI-TOF MS (positive mode, trihydroxyacetophenone as matrix) [M-H]⁺ m/z_{exp} = 957.01, m/z_{calc} = 957.07; HPLC (spectrophotometrical purity at 260 nm = 95 %).

Example 13

Synthesis of the dimer 5'-OH-dG^{IBu}-dA^{Bz}-3'-O-TBDMS cyanoethyl phosphorothioate triester.

Coupling procedure of 5'-O-DMTr-dG^{IBu}-3'-cyanoethyl-phosphoramidite with 5'-OH-dA^{Bz}-3'-O-TBDMS using the poly(4-vinylpyridinium *p*-toluenesulfonate) (Aldrich):

5'-OH-dA-3'-O-TBDMS (100 mg, 0.21 mmol) and 5'-O-DMTr-dG^{IBu}-3'-cyanoethyl-phosphoramidite (352 mg, 0.42 mmol, 1.97 eq) are dissolved in anhydrous acetonitrile (20 ml). The solution is transferred under argon in a flask containing the poly(4-vinylpyridinium *p*-toluenesulfonate) (655 mg, 2.19 mmol tos⁻, 10.3 eq) and is shaken for 5 h 30 min. The reaction is followed by ³¹P NMR. The yield is determined by ³¹P NMR. The desired dG-dA phosphite triester dimer is obtained with 100% of yield compared to the 5'-OH-dA^{Bz}-3'-O-TBDMS. The crude is a mixture of 5'-O-DMTr-dG^{IBu}-dA^{Bz}-3'-O-TBDMS cyano-

ethyl phosphite triester (^{31}P NMR (CD_3CN) (δ 140.65, 140.45; 51.2%), 5'-O-DMTr-dG^{IBu}-3'-cyanoethyl hydrogenophosphonate (δ 9.00, 8.81; 48.8%).

Sulfurization: To a solution of 5'-O-DMTr-dG^{IBu}-dA^{Bz}-3'-O-TBDMS cyanoethyl

phosphite triester dimer (0.21 mmol) in anhydrous acetonitrile is added

5 AMBERLYST A26 tetrathionate form (0.63 g, 1.14 mmol $\text{S}_4\text{O}_6^{2-}$, 5.4 eq.). The reaction mixture is shaken for 2 h. The reaction is followed by ^{31}P NMR. The yield is determined by ^{31}P NMR. After filtration of the resins the desired dG-dA phosphorothioate triester dimer is obtained with 100% of yield compared to the 5'-OH-dA^{Bz}-3'-O-TBDMS. The crude is a mixture of 5'-O-DMTr-dG^{IBu}-dA^{Bz}-
10 3'-O-TBDMS cyanoethyl phosphorothioate (^{31}P NMR (CD_3CN) (δ 68.15, 68.02; 50.4%), 5'-O-DMTr-dG^{IBu}-3'-cyanoethyl hydrogenophosphonate (δ 8.91, 8.68; 49.6%).

Detritylation: To a solution of 5'-O-DMTr-dG^{IBu}-dA^{Bz}-3'-O-TBDMS cyanoethyl phosphorothioate triester (0.21 mmol) in 10 ml $\text{CH}_2\text{Cl}_2/\text{CH}_3\text{OH}$ (7/3) is added

15 0.5 ml (0.3 mmol, 1.4 eq.) of a solution of benzene sulfonic acid 10% in $\text{CH}_2\text{Cl}_2/\text{CH}_3\text{OH}$ (7/3). The solution is stirred 20 min at 0°C. The reaction is washed with 10 ml of a saturated solution of NaHCO_3 , the organic layer is separated, dried (Na_2SO_4), evaporated, and purified on a silica gel column. The desired G-A dimer is eluted with $\text{CH}_2\text{Cl}_2/\text{CH}_3\text{OH}$ (33/1). The appropriate fractions are collected and evaporated to give a white foam. Yield: 95 mg, 0.1 mmol, 48% with respect of 5'-OH-dA-3'-O-TBDMS; ^{31}P NMR (CD_3CN) δ 68.10, 67.87; HPLC (spectrophotometrical purity at 260 nm = 80%).

Example 14

Synthesis of the dimer 5'-OH-dG^{IBu}-dC^{Bz}-3'-O-TBDMS cyanoethyl phosphorothioate triester.

Coupling procedure of 5'-O-DMTr-dG^{IBu}-3'-cyanoethyl-phosphoramidite with 5'-OH-dC^{Bz}-3'-O-TBDMS using the poly(4-vinylpyridinium *p*-toluenesulfonate) (Aldrich):

30 5'-OH-dC^{Bz}-3'-O-TBDMS (100 mg, 0.22 mmol) and 5'-O-DMTr-dG^{IBu}-3'-cyanoethyl- phosphoramidite (371 mg, 0.45 mmol, 2 eq) are dissolved in anhydrous acetonitrile (15 ml). The solution is transferred under argon in a flask containing the poly(4-vinylpyridinium *p*-toluenesulfonate) (690 mg, 2.3 mmol tos⁻, 10.3 eq) and is shaken for 5 h. The reaction is followed by ^{31}P NMR. The yield is determined by ^{31}P NMR. The desired dG-dC phosphite triester dimer is obtained with 100% of yield compared to the 5'-OH-dC^{Bz}-3'-O-TBDMS. The

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crude is a mixture of 5'-O-DMTr-dG^{IBu}-dC^{Bz}-3'-O-TBDMS cyanoethyl phosphite triester (³¹P NMR (CD₃CN) (δ 141.73, 141.26; 62.1%), 5'-O-DMTr-dG^{IBu}-3'-cyanoethyl hydrogeno-phosphonate (δ 9.05, 8.88; 37.9%).

Sulfurization: To a solution of 5'-O-DMTr-dG^{IBu}-dC^{Bz}-3'-O-TBDMS cyanoethyl phosphite triester dimer (0.22 mmol) in anhydrous acetonitrile is added AMBERLYST A26 tetrathionate form (0.65 g, 1.3 mmol S₄O₆²⁻, 5.4 eq.). The reaction mixture is shaken for 2 h. The reaction is followed by ³¹P NMR. The yield is determined by ³¹P NMR. After filtration of the resins the desired dG-dC phosphorothioate triester dimer is obtained with 100% of yield compared to the 5'-OH-dC^{Bz}-3'-O-TBDMS. The crude is a mixture of 5'-O-DMTr-dG^{IBu}-dC^{Bz}-3'-O-TBDMS cyanoethyl phosphorothioate (³¹P NMR (CD₃CN) (δ 68.12, 67.73; 61.2%), 5'-O-DMTr-dG^{IBu}-3'-cyanoethyl phosphorothioate diester (δ 56.51, 56.39; 25.4%), 5'-O-DMTr-dG^{IBu}-3'-cyanoethyl hydrogenophosphonate (δ 9.04, 8.85; 25.4%). ³¹P NMR d.

Detritylation: To a solution of 5'-O-DMTr-dG^{IBu}-dC^{Bz}-3'-O-TBDMS cyanoethyl phosphorothioate triester (0.22 mmol) in 10 ml CH₂Cl₂/CH₃OH (7/3) is added 0.5 ml (0.3 mmol, 1.4 eq.) of a solution of benzene sulfonic acid 10% in CH₂Cl₂/CH₃OH (7/3). The solution is stirred 1 h at 0°C. The reaction is washed with 10 ml of a saturated solution of NaHCO₃, the organic layer is separated, dried (Na₂SO₄) and evaporated. The crude product is purified on a silica gel column using CH₂Cl₂/CH₃OH (33:1). The appropriate fractions are collected and evaporated to give a colorless oil. Yield: 99 mg, 0.1 mmol, 47%; ³¹P NMR (CD₃CN) δ 67.82, 67.56; MALDI-TOF MS (positive mode, trihydroxyacetophenone as matrix) [M-H]⁺ m/z_{exp} = 914.78, m/z_{calc} = 914.03; HPLC (spectrophotometrical purity at 260 nm = 84%).

Example 15

Synthesis of 5'-O-DMTr-T-T-3'-O-DMTr-phosphorothioate diester.

To a solution of 5'-O-DMTr-T-T-3'-O-DMTr H-phosphonate diester (25 mg, 22 mmol) in dichloromethane is added AMBERLYST A26 tetrathionate form (170 mg, 0.29 mmol S₄O₆²⁻, 13 eq.) and 0.1 mL triethylamine. The reaction mixture is shaken for 78 h. The title compound was isolated after filtration of the resin and evaporation of the solvent. Yield: 28 mg, 22 mmol, 100%; ³¹P NMR (CD₃CN) δ 57.22; MALDI-TOF MS (negative mode, trihydroxy-acetophenone as matrix) [M-H]⁻ m/z_{exp} = 1166.23, m/z_{calc} = 1666.25.

Example 16*Synthesis of 5'-O-DMTr-T-T-3'-O-TBDMS-phosphorothioate diester.*

To a solution of 5'-O-DMTr-T-T-3'-O-TBDMS *H*-phosphonate (55 mg, 58 mmol) in dichloromethane is added AMBERLYST A26 tetrathionate form (250 mg,

5 0.42 mmol $S_4O_6^{2-}$, 7.3 eq.) and 0.2 mL triethylamine. The reaction mixture is shaken for 26 h. The title compound was isolated after filtration of the resin and evaporation of the solvent. Yield: 63 mg, 58 mmol, 100%; ^{31}P NMR (CD₃CN) δ 57.78, 57.72; MALDI-TOF MS (negative mode, trihydroxyacetophenone as matrix) [M-H]⁻ m/z_{exp} = 977.04, m/z_{calc} = 977.13.

Example 17*Synthesis of AMBERLYST A26 tetrathionate form.*

10 g commercial Amberlyst A26 hydroxide form (Rohm & Haas) is washed twice with 20 mL methanol and twice with 20 mL dichloromethane and dried in vacuum. Potassium tetrathionate (30.35 g, 100 mmol, 3 eq.) is dissolved in

15 200 mL deionized water. The solution is added to the resin and shaken for 20 hours. The solution is decanted off. The resin is washed with 4 L deionized water, twice with 100 mL methanol and twice with 100 mL dichloromethane and dried under reduced pressure for 3 hours to give 8.5 g of solid-supported tetrathionate. The reagents loading was determined by elemental analysis, 20 giving a value of 23.25% for sulfur (4.24% for nitrogen, 45.74% for carbon and less than 100 ppm for potassium). Loading: 1.81 mmol $S_4O_6^{2-}$ per gram of resin.

Example 18*Synthesis of polymer-supported pyridinium*

25 The commercially available strongly acidic ion-exchange resin DOWEX 50W X8 H⁺ form (Fluka) is washed successively with water, HCl 2M, water until pH 7, methanol and dichloromethane to dry the resin. Then, the resin is stirred in a solution of pyridine 2M in acetonitrile or just washed with a slight flow of the solution of pyridine 2M in acetonitrile for 15 minutes. Then, the resin is washed 30 with acetonitrile and dichloromethane and dried under vacuum over P₂O₅. The reagents loading was determined by elemental analysis, giving a value of 11.56% for sulfur and 3.97% for nitrogen. Loading: 2.83 mmol pyrH⁺ per gram of resin.

Example 19*Preparation of polystyrene-bound acid chloride*

The commercial polystyrene-bound carboxy acid RAPP Polymere (5.0 g, 1.96 mmol/g, 100-200 mesh, 1% DVB) is suspended in anhydrous CH_2Cl_2 (80 ml) and N,N-dimethylformamide (0.3 ml). Thionyl chloride (1.8 ml, 3.5 eq) are added under stirring and the mixture is refluxed for 3h. The resin is filtered under argon and washed with dried CH_2Cl_2 (100 ml), ether (100 ml) and dried under vacuum for 4h.

IR (cm^{-1}): 1775 (C=O, Acid chloride)

Elemental analysis: Cl 7.43% (w/100g resin) (2.09 mmol/g)

Chloride titration: 2.1 mmol/g

Example 20*Synthesis of 5'-O-DMTr-dA^{Bz}-dC^{Bz}-3'-O-Lev H-phosphonate*

A solution of 5'-O-DMTr-dA^{Bz}-H-phosphonate TEA salt (123.4 mg, 0.150 mmol) and of 3'-O-Lev-dC^{Bz} (53.7 mg, 0.125 mmol) in 2.0 ml of $\text{CH}_2\text{Cl}_2/\text{py}$ (1:1) is added to polystyrene-bound acid chloride (388.8 mg, 2.1 mmol/g, 5.5 eq) that is suspended in 2.5 ml of the same solvent. The mixture is shaken for 1h at room temperature until the disappearance of the monomers. The reaction is monitored by reverse phase HPLC. The resin is filtered, washed with CH_2Cl_2 . The pyridinium salt present in solution is removed by aqueous extraction and the aqueous phase is washed twice with CH_2Cl_2 . The organic fractions are collected, dried over Na_2SO_4 , the solvent is evaporated and the pyridine is eliminated by coevaporation with toluene. The isolated product was dried under vacuum. Yield 89%.

^{31}P NMR (CD_3CN) δ 10.03 ppm, 9.46 ppm.

MALDI-TOF MS (positive mode, trihydroxyacetophenone as matrix) $[\text{M}+\text{H}]^+$
 $m/z_{\text{exp}} = 1134.13$, $m/z_{\text{calc}} = 1133.51$.

The spectrophotometrical purity determined by HPLC is 93%.

Example 21*Synthesis of 5'-O-DMTr-dA^{Bz}-T-3'-O-Lev H-phosphonate*

A solution of 5'-O-DMTr-dA^{Bz}-H-phosphonate TEA salt (123.4 mg, 0.150 mmol) and of 3'-O-Lev-T (42.5 mg, 0.125 mmol) in 2.0 ml of $\text{CH}_2\text{Cl}_2/\text{py}$ (1:1) is

added to polystyrene-bound acid chloride (550.0 mg, 2.1 mmol/g, 7.7 eq) that is suspended in 5.0 ml of the same solvent. The mixture is shaken for 30 min at room temperature until the disappearance of the monomers. The reaction is monitored by reverse phase HPLC. The resin is filtered, washed with CH_2Cl_2 .

5 The pyridinium salt present in solution is removed by aqueous extraction and the aqueous phase is washed twice with CH_2Cl_2 . The organic fractions are collected, dried over Na_2SO_4 , the solvent is evaporated and the pyridine is eliminated by coevaporation with toluene. The isolated product is dried under vacuum. Yield 88.5%

10 ^{31}P NMR (CD_3CN) δ 10.02 ppm, 9.08 ppm.

MALDI-TOF MS (positive mode, trihydroxyacetophenone as matrix) $[\text{M}+\text{H}]^+$ $m/z_{\text{exp}} = 1043.02$, $m/z_{\text{calc}} = 1045.00$.

The spectrophotometrical purity determined by HPLC is 98%.

Example 22

15 *Synthesis of 5'-O-DMTr-T-dC^{Bz} -3'-O-TBDMS H-phosphonate*

A solution of 5'-O-DMTr-T-H-phosphonate TEA salt (106.4 mg, 0.150 mmol) and of 3'-O-TBDMS-dC^{Bz} (55.7 mg, 0.125 mmol) in 2.0 ml of $\text{CH}_2\text{Cl}_2/\text{py}$ (1:1) is added to polystyrene-bound acid chloride (555.0 mg, 2.7 mmol/g, 10 eq) that is suspended in 5.0 ml of the same solvent. The mixture is shaken for 2h at room temperature until the disappearance of the monomers. The reaction is monitored by reverse phase HPLC. The resin is filtered, washed with CH_2Cl_2 . The pyridinium salt present in solution is removed by aqueous extraction and the aqueous phase is washed twice with CH_2Cl_2 . The organic fractions are collected, dried over Na_2SO_4 , the solvent is evaporated and the pyridine is eliminated by coevaporation with toluene. The isolated product is dried under vacuum. Yield 77.5%.

20 ^{31}P NMR (CD_3CN) δ 10.50 ppm, 10.00 ppm.

MALDI-TOF MS (positive mode, trihydroxyacetophenone as matrix) $[\text{M}+\text{H}]^+$ $m/z_{\text{exp}} = 1038.69$, $m/z_{\text{calc}} = 1037.20$.

25 The spectrophotometrical purity determined by HPLC is 94%.

Example 23

Synthesis of 5'-O-DMTr -T-dC^{Bz}-3'-O-TBDMS phosphorothioate TEA salt

A solution of 5'-O-DMTr -T-dC^{Bz}-3'-O-TBDMS H-phosphonate (50 mg, 0.048

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mmol) in 5.0 ml of CH_2Cl_2 and 0.2 ml TEA is added to Amberlyst A26 tetra-thionate form (141.0 mg, 1.7 mmol/g, 5 eq). The mixture is shaken over night, the the resin is filtered and the solvent is evaporated. The product is dried under vacuum. Yield 100%.

5 ^{31}P NMR (CD_2Cl_2) δ 59.17 ppm, 58.99 ppm.

The spectrophotometrical purity determined by HPLC is 95%.

Example 24

Synthesis of 5'-O-DMTr-dA^{Bz}-T-3'-O-Lev phosphate TEA salt

A solution of 5'-O-DMTr-dA^{Bz}-T-3'-O-Lev H-phosphonate (90 mg, 0.0863 mmol) in 5.0 ml of CH_2Cl_2 and 0.2 ml TEA is added to (polystyrylmethyl)trimethylammonium metaperiodate (NOVABIOCHEM) (173.0 mg, 2.5 mmol/g, 5 eq). The mixture is shaken over night, the resin is filtered and the solvent is evaporated. The product is dried under vacuum. Yield 100%.

15 ^{31}P NMR (CD_2Cl_2) δ -1.37 ppm.

MALDI-TOF MS (positive mode, trihydroxyacetophenone as matrix) $[\text{M}+\text{H}]^+$ $m/z_{\text{exp}} = 1059.31$, $m/z_{\text{calc}} = 1060.03$.

The spectrophotometrical purity determined by HPLC is 87%.

Example 25

20 *Synthesis of 5'-O-DMTr-T-dA^{Bz}-dC^{Bz}-3'-O-Lev H-phosphonate*

Detritylation of 5'-O-DMTr-dA^{Bz}-dC^{Bz}-3'-O-Lev H-phosphonate

The H-phosphonate dimer 5'-O-DMTr-dA^{Bz}-dC^{Bz}-3'-O-Lev (120 mg, 0.106 mmol) is dissolved in 4.0 ml of CH_2Cl_2 /MeOH (7:3) and cooled in an ice bath. To this solution 1.0 ml of a solution of 10% BSA (benzene sulfonic acid) in 25 CH_2Cl_2 /MeOH (7:3) is added drop wise under stirring and the progress of the reaction is monitored by TLC. After 15 min the mixture is quenched with a solution of NaHCO_3 . The organic layer is washed with water to remove any trace of base, then it is dried over Na_2SO_4 and the solvent is evaporated. The product is purified by precipitation from CH_2Cl_2 with ether and dried under 30 vacuum. Yield 88%.

MALDI-TOF MS (positive mode, trihydroxyacetophenone as matrix) $[\text{M}+\text{H}]^+$ $m/z_{\text{exp}} = 830.75$, $m/z_{\text{calc}} = 831.75$.

The spectrophotometrical purity determined by HPLC is 91%.

Coupling

A solution of 5'-O-DMTr-T-H-phosphonate TEA salt (93.8 mg, 0.132 mmol) and of 5'-OH-dA^{Bz}-dC^{Bz}-3'-O-Lev H-phosphonate (73.2 mg, 0.088 mmol) in 2.0 ml of CH₂Cl₂/py (1:1) is added to polystyrene-bound acid chloride (503.0 mg, 2.1 mmol/g, 8 eq) that is suspended in 4.0 ml of the same solvent. The mixture is shaken for 1h at room temperature until the disappearance of the monomers. The reaction is monitored by reverse phase HPLC. The resin is filtered, washed with CH₂Cl₂. The pyridinium salt present in solution is removed by aqueous extraction and the aqueous phase is washed twice with CH₂Cl₂. The organic fractions are collected, dried over Na₂SO₄, the solvent is evaporated and the pyridine is eliminated by coevaporation with toluene. The isolated product is dried under vacuum. Yield 82%.

³¹P NMR (CD₂Cl₂) δ 10.23, 10.09, 9.70, 9.68, 9.52, 9.30, 9.24, 9.19 ppm.
15 MALDI-TOF MS (positive mode, trihydroxyacetophenone as matrix) [M+H]⁺ m/z_{exp} = 1421.06, m/z_{calc} = 1422.33.

The spectrophotometrical purity determined by HPLC is 82%.

Example 26

Synthesis of 5'-O-DMTr-dA^{Bz}-dA^{Bz}-T-3'-O-Lev H-phosphonate

20 Detritylation of 5'-O-DMTr-dA^{Bz}-T-3'-O-Lev H-phosphonate

The H-phosphonate dimer 5'-O-DMTr-dA^{Bz}-T-3'-O-Lev (105 mg, 0.100 mmol) is dissolved in 4.0 ml of CH₂Cl₂/MeOH (7:3) and cooled in an ice bath. 1.0 ml of a solution of 10% BSA in CH₂Cl₂/MeOH (7:3) is added drop wise under stirring and the progress of the reaction is monitored by TLC. After 15 min the mixture is quenched with a solution of NaHCO₃. The organic layer is washed with water to remove any trace of base, then it is dried over Na₂SO₄ and the solvent is evaporated. The product is purified by precipitation from CH₂Cl₂ in ether and dried under vacuum. Yield 70%.

30 MALDI-TOF MS (positive mode, trihydroxyacetophenone as matrix) [M+H]⁺ m/z_{exp} = 742.25, m/z_{calc} = 742.66.

The spectrophotometrical purity determined by HPLC is 92%.

Coupling

A solution of 5'-O-DMTr-dA^{Bz}-H-phosphonate TEA salt (69.8 mg, 0.084 mmol) and of 5'-OH-dA^{Bz}-dT-3'-O-Lev H-phosphonate (52.2 mg, 0.070 mmol) in 2.0 ml of CH₂Cl₂/py (1:1) is added to polystyrene-bound acid chloride (311.0 mg,

5 2.1 mmol/g, 7.7 eq) that is suspended in 2.0 ml of the same solvent. The mixture is shaken for 3h at room temperature until the disappearance of the monomers. The reaction is monitored by reverse phase HPLC. The resin is filtered, washed with CH₂Cl₂. The pyridinium salt present in solution is removed by aqueous extraction and the aqueous phase is washed twice with CH₂Cl₂.
10 The organic fractions are collected, dried over Na₂SO₄, the solvent is evaporated and the pyridine is eliminated by coevaporation with toluene. The isolated product is dried under vacuum. Yield 75%.

³¹P NMR (CD₂Cl₂) δ 10.09, 9.39, 8.82, 8.76, 8.30, 7.56 ppm.

MALDI-TOF MS (positive mode, trihydroxyacetophenone as matrix) [M+H]⁺
15 m/z_{exp} = 1445.60, m/z_{calc} = 1447.40.

The spectrophotometrical purity determined by HPLC is 91.5%.

Example 27

Synthesis of the dimer 5'-OH-T-dG^{IBu}-3'-O-Lev cyanoethyl phosphorothioate triester.

20 **Coupling procedure** of 5'-O-DMTr-T-3'-cyanoethyl-phosphoramidite with 5'-OH-dG^{IBu}-3'-O-Lev using the poly(4-vinylpyridinium p-toluenesulfonate) (Aldrich):

5'-OH-dG^{IBu}-3'-O-Lev (201 mg, 0.46 mmol) and 5'-O-DMTr-T-3'-cyanoethyl-phosphoramidite (620 mg, 0.83 mmol, 1.8 eq) are dissolved in anhydrous dichloromethane (10 ml). The solution is transferred under argon in a flask containing the poly(4-vinylpyridinium p-toluenesulfonate) (1.38 g, 4.6 mmol tos⁻, 10 eq) and is shaken for 3 h. The resin is filtered off. The reaction is followed by reverse phase HPLC and ³¹P NMR. The yield is determined by ³¹P NMR. The desired T-dG phosphite triester dimer is obtained with 100% of yield
30 compared to the 5'-OH-dG^{IBu}-3'-O-Lev. The crude is a mixture of 5'-O-DMTr-T-dG^{IBu}-3'-O-Lev cyanoethyl phosphite triester ³¹P NMR (CDCl₃) (d 140.76, 139.97; 60.7%) and 5'-O-DMTr-T-3'-cyanoethyl hydrogenophosphonate (d 8.10, 8.03; 39.3%).

Sulfurization: To a solution of 5'-O-DMTr-T-dG^{IBu}-3'-O-Lev cyanoethyl

phosphite triester dimer (0.46 mmol) in anhydrous dichloromethane is added AMBERLYST A26 tetrathionate form (1.28 g, 2.3 mmol $S_4O_6^{2-}$, 5 eq.). The reaction mixture is shaken for 2 h. The reaction is followed by reverse phase HPLC and ^{31}P NMR. The yield is determined by ^{31}P NMR. After filtration of the 5 resin the desired T-dG phosphorothioate triester dimer is obtained with 100% of yield compared to the 5'-OH-dG^{IBu}-3'-O-Lev. The crude is a mixture of 5'-O-DMTr-T-dG^{IBu}-3'-O-Lev cyanoethyl phosphorothioate ^{31}P NMR ($CDCl_3$) (d 67.99, 67.71; 64.7%) and 5'-O-DMTr-T-3'-cyanoethyl hydrogenophosphonate (d 8.09, 8.02; 35.3%); MALDI-TOF MS (positive mode, trihydroxyacetophenone 10 as matrix) $[M-DMTr]^{+}$ $m/z_{exp} = 809.00$, $m/z_{calc} = 809.77$.

Detritylation: To a solution of 5'-O-DMTr-T-dG^{IBu}-3'-O-Lev cyanoethyl phosphorothioate triester (0.46 mmol) in 20 ml CH_2Cl_2/CH_3OH (7/3) is added 2 ml (1.2 mmol, 1.4 eq.) of a solution of benzene sulfonic acid 10% in CH_2Cl_2/CH_3OH (7/3). The solution is stirred 25 min at 0°C. The reaction is 15 washed with 10 ml of a saturated solution of $NaHCO_3$, the organic layer is separated, dried ($MgSO_4$) and evaporated. The crude product is dissolved in 3.5 mL dichloromethane and added to 50 mL diethylether at 0°C to give a white precipitate. Yield: 370 mg, 0.46 mmol, 99%; ^{31}P NMR ($CDCl_3$) d 67.77, 67.42; MALDI-TOF MS (positive mode, trihydroxyacetophenone as matrix) $[M-H]^{+}$ $m/z_{exp} = 910.42$, $m/z_{calc} = 909.77$; HPLC HPLC (7.27 min; Area = 85%).

Example 28

Synthesis of the dimer 5'-OH-dA^{Bz}-dG^{IBu}-3'-O-Lev cyanoethyl phosphorothioate triester.

Coupling procedure of 5'-O-DMTr-dA^{Bz}-3'-cyanoethyl-phosphoramidite with 25 5'-OH-dG^{IBu}-3'-O-Lev using the poly(4-vinylpyridinium *p*-toluenesulfonate) (Aldrich):

5'-OH-dG^{IBu}-3'-O-Lev (200 mg, 0.46 mmol) and 5'-O-DMTr-dA^{Bz}-3'-cyanoethyl-phosphoramidite (713 mg, 0.83 mmol, 1.8 eq) are dissolved in anhydrous dichloromethane (10 ml). The solution is transferred under argon in a flask 30 containing the poly(4-vinylpyridinium *p*-toluenesulfonate) (1.38 g, 4.6 mmol tos⁻, 10 eq) and is shaken for 2 h. The resin is filtered off. The reaction is followed by reverse phase HPLC and ^{31}P NMR. The yield is determined by HPLC. The desired dA^{Bz}-dG phosphite triester dimer (HPLC at 11.34 min; Area = 61%) is obtained with 100% of yield compared to the 5'-OH-dG^{IBu}-3'-O-Lev 35 (HPLC at 6.34 min; Area = 0%). The crude is a mixture of 5'-O-DMTr-dA^{Bz}-dG^{IBu}-3'-O-Lev cyanoethyl phosphite triester ^{31}P NMR ($CDCl_3$) (d 140.82,

140.30), 5'-O-DMTr-dA^{Bz}-3'-cyanoethyl phosphoramidite (d 149.90) and 5'-O-DMTr-dA^{Bz}-3'-cyanoethyl hydrogeno-phosphonate (d 8.20, 8.03).

Sulfurization: To a solution of 5'-O-DMTr-dA^{Bz}-dG^{tBu}-3'-O-Lev cyanoethyl phosphite triester dimer (0.46 mmol) in anhydrous dichloromethane is added 5 AMBERLYST A26 tetrathionate form (1.28 g, 2.3 mmol S₄O₆²⁻, 5 eq.). The reaction mixture is shaken for 2 h. The reaction is followed by reverse phase HPLC and ³¹P NMR. The yield is determined by HPLC. After filtration of the resin the desired dA^{Bz}-dG phosphorothioate triester dimer (HPLC at 11.49 min; Area = 61%) is obtained with 100% of yield compared to the 5'-OH-dG^{tBu}-3'-O-Lev. The crude is a mixture of 5'-O-DMTr-dA^{Bz}-dG^{tBu}-3'-O-Lev cyanoethyl phosphorothioate ³¹P NMR (CDCl₃) (d 68.01, 67.93), 5'-O-DMTr-dA^{Bz}-3'-cyanoethyl thiophosphoramidate (d 71.86, 71.54) and 5'-O-DMTr-dA^{Bz}-3'-cyanoethyl hydrogenophosphonate (d 8.20, 8.03); MALDI-TOF MS (positive mode, trihydroxyacetophenone as matrix) [M-H]⁺ m/z_{exp} = 1224.14, m/z_{calc} = 15 1225.27.

Detritylation: To a solution of 5'-O-DMTr-dA^{Bz}-dG^{tBu}-3'-O-Lev cyanoethyl phosphorothioate triester (0.46 mmol) in 20 ml CH₂Cl₂/CH₃OH (7/3) is added 2 ml (1.2 mmol, 1.4 eq.) of a solution of benzene sulfonic acid 10 % in CH₂Cl₂/CH₃OH (7/3). The solution is stirred 20 min at 0°C. Another 1 ml (0.6 mmol, 0.7 eq.) of a solution of benzene sulfonic acid 10% in CH₂Cl₂/CH₃OH (7/3) is added and the solution is stirred for 40 min. The reaction is washed with 10 ml of a saturated solution of NaHCO₃, the organic layer is separated, dried (MgSO₄) and evaporated. The crude product is dissolved in 4 mL dichloromethane and added to 50 mL diethylether at 0°C to give a white precipitate. Yield: 442 mg, 0.4 mmol, 87%; ³¹P NMR (CDCl₃) d 68.09, 67.78; MALDI-TOF MS (positive mode, trihydroxyacetophenone as matrix) [M-H]⁺ m/z_{exp} = 923.03, m/z_{calc} = 922.89; HPLC (8.08 min; Area = 85%).

Example 29

Synthesis of the dimer 5'-OH-dC^{Bz}-dG^{tBu}-3'-O-Lev cyanoethyl phosphorothioate triester.

Coupling procedure of 5'-O-DMTr-dC^{Bz}-3'-cyanoethyl-phosphoramidite with 5'-OH-dG^{tBu}-3'-O-Lev using the poly(4-vinylpyridinium *p*-toluenesulfonate) (Aldrich):

35 5'-OH-dG^{tBu}-3'-O-Lev (200 mg, 0.46 mmol) and 5'-O-DMTr-dC^{Bz}-3'-cyanoethyl-phosphoramidite (694 mg, 0.83 mmol, 1.8 eq) are dissolved in anhydrous dichloromethane (10 ml). The solution is transferred under argon in a flask

containing the poly(4-vinylpyridinium *p*-toluenesulfonate) (1.38 g, 4.6 mmol tos⁻, 10 eq) and is shaken for 3 h. The resin is filtered off. The reaction is followed by reverse phase HPLC and ³¹P NMR. The yield is determined by HPLC. The desired dC-dG phosphite triester dimer (HPLC at 12.01 min; Area = 50 %) 5 is obtained with 100% of yield compared to the 5'-OH-dG^{IBu}-3'-O-Lev (HPLC at 6.34 min; Area = 0%). The crude is a mixture of 5'-O-DMTr-dC^{Bz}-dG^{IBu}-3'-O-Lev cyanoethyl phosphite triester ³¹P NMR (CDCl₃) (d 140.67, 140.59), 5'-O-DMTr-dC^{Bz}-3'-cyanoethyl phosphoramidite (d 149.93) and 5'-O-DMTr-dC^{Bz}-3'-cyanoethyl hydrogeno-phosphonate (d 8.08).
10 **Sulfurization:** To a solution of 5'-O-DMTr-dC^{Bz}-dG^{IBu}-3'-O-Lev cyanoethyl phosphite triester dimer (0.46 mmol) in anhydrous dichloromethane is added AMBERLYST A26 tetrathionate form (1.37 g, 2.5 mmol S₄O₆²⁻, 5.4 eq.). The reaction mixture is shaken for 3 h. The reaction is followed by reverse phase HPLC and ³¹P NMR. The yield is determined by HPLC. After filtration of the 15 resin the desired dC-dG phosphorothioate triester dimer (HPLC at 12.26 min; Area = 59%) is obtained with 100% of yield compared to the 5'-OH-dG^{IBu}-3'-O-Lev. The crude is a mixture of 5'-O-DMTr-dC^{Bz}-dG^{IBu}-3'-O-Lev cyanoethyl phosphorothioate ³¹P NMR (CDCl₃) (d 68.02, 67.55), 5'-O-DMTr-dC^{Bz}-3'-cyanoethyl thiophosphoramidate (d 71.93, 71.62) and 5'-O-DMTr-dC^{Bz}-3'-cyanoethyl hydrogeno-phosphonate (d 8.07).
20

Detritylation: To a solution of 5'-O-DMTr-dC^{Bz}-dG^{IBu}-3'-O-Lev cyanoethyl phosphorothioate triester (0.46 mmol) in 20 ml CH₂Cl₂/CH₃OH (7/3) is added 2 ml (1.2 mmol, 1.4 eq.) of a solution of benzene sulfonic acid 10 % in CH₂Cl₂/CH₃OH (7/3). The solution is stirred 20 min at 0°C. Another 1 ml (0.6 mmol, 0.7 eq.) of a solution of benzene sulfonic acid 10 % in CH₂Cl₂/CH₃OH (7/3) is added and the solution is stirred for 10 min. The reaction is washed with 10 ml of a saturated solution of NaHCO₃, the organic layer is separated, dried (MgSO₄) and evaporated. The crude product is dissolved in 7 mL dichloromethane and added to 50 mL diethylether at 0°C to give a white precipitate. Yield: 493 mg, 0.33 mmol, 71%; ³¹P NMR (CDCl₃) d 67.38, 66.77; MALDI-TOF MS (positive mode, trihydroxyacetophenone as matrix) [M-H]⁺ 25 m/z_{exp} = 898.84, m/z_{calc} = 898.86; HPLC (8.34 min; Area = 60 %).
30

Example 30

Synthesis of the dimer 5'-OH-dG^{IBu}-dG^{IBu}-3'-O-Lev cyanoethyl phosphorothioate triester. 35

Coupling procedure of 5'-O-DMTr-dG^{IBu}-3'-cyanoethyl-phosphoramidite with

5'-OH-dG^{tBu}-3'-O-Lev using the poly(4-vinylpyridinium *p*-toluenesulfonate) (Aldrich):

5'-OH-dG^{tBu}-3'-O-Lev (200 mg, 0.46 mmol) and 5'-O-DMTr-dG^{tBu}-3'-cyanoethyl-phosphoramidite (698 mg, 0.84 mmol, 1.8 eq) are dissolved in 5 anhydrous dichloromethane (10 ml). The solution is transferred under argon in a flask containing the poly(4-vinylpyridinium *p*-toluenesulfonate) (1.38 g, 4.6 mmol tos⁻, 10 eq) and is shaken for 1 h 15 min. The resin is filtered off. The reaction is followed by reverse phase HPLC and ³¹P NMR. The yield is determined by HPLC. The desired dG-dG phosphite triester dimer (HPLC at 11.01 10 min; Area = 65%) is obtained with 100% of yield compared to the 5'-OH-dG^{tBu}-3'-O-Lev (HPLC at 6.34 min; Area = 0%). The crude is a mixture of 5'-O-DMTr-dG^{tBu}-dG^{tBu}-3'-O-Lev cyanoethyl phosphite triester ³¹P NMR (CDCl₃) (d 141.91, 140.29) and 5'-O-DMTr-dG^{tBu}-3'-cyanoethyl hydrogenophosphonate (d 8.80, 8.06).

15 **Sulfurization:** To a solution of 5'-O-DMTr-dG^{tBu}-dG^{tBu}-3'-O-Lev cyanoethyl phosphite triester dimer (0.46 mmol) in anhydrous dichloromethane is added AMBERLYST A26 tetrathionate form (1.28 g, 2.3 mmol S₄O₆²⁻, 5 eq.). The reaction mixture is shaken for 1 h 20 min. The reaction is followed by reverse 20 phase HPLC and ³¹P NMR. The yield is determined by HPLC. After filtration of the resin the desired dG-dG phosphorothioate triester dimer (HPLC at 11.52 min; Area = 75%) is obtained with 100 % of yield compared to the 5'-OH-dG^{tBu}-3'-O-Lev. The crude is a mixture of 5'-O-DMTr-dG^{tBu}-dG^{tBu}-3'-O-Lev cyanoethyl phosphorothioate ³¹P NMR (CDCl₃) (d 68.61, 67.64) and 5'-O-DMTr-dG^{tBu}-3'-cyanoethyl hydrogenophosphonate (d 8.07); MALDI-TOF MS (positive 25 mode, trihydroxyacetophenone as matrix) [M-DMTr]⁺ m/z_{exp} = 904.14, m/z_{calc} = 904.87.

30 **Detritylation:** To a solution of 5'-O-DMTr-dG^{tBu}-dG^{tBu}-3'-O-Lev cyanoethyl phosphorothioate triester (0.46 mmol) in 20 ml CH₂Cl₂/CH₃OH (7/3) is added 2 ml (1.2 mmol, 1.4 eq.) of a solution of benzene sulfonic acid 10 % in CH₂Cl₂/CH₃OH (7/3). The solution is stirred 25 min at 0°C. The reaction is washed with 10 ml of a saturated solution of NaHCO₃, the organic layer is separated, dried (MgSO₄) and evaporated. The crude product is dissolved in 7.5 mL dichloromethane and added to 50 mL diethylether at 0°C to give a white precipitate. Yield: 450 mg, 0.41 mmol, 88 ; ³¹P NMR (CDCl₃) d 67.85, 35 67.66; MALDI-TOF MS (positive mode, trihydroxyacetophenone as matrix) [M-H]⁺ m/z_{exp} = 905.45, m/z_{calc} = 904.87; HPLC (7.95 min; Area = 82%).

Example 31

Synthesis of the trimer 5'-OH-dA^{Bz}-T-dG^{IBu}-3'-O-Lev cyanoethyl phosphorothioate triester.

Coupling procedure of 5'-O-DMTr-dA^{Bz}-3'-cyanoethyl-phosphoramidite with

5 5'-OH-T-dG^{IBu}-3'-O-Lev cyanoethyl phosphorothioate triester using the poly(4-vinylpyridinium *p*-toluenesulfonate) (Aldrich):

10 5'-OH-T-dG^{IBu}-3'-O-Lev cyanoethyl phosphorothioate triester (362 mg, 0.4 mmol) and 5'-O-DMTr-dA^{Bz}-3'-cyanoethyl-phosphoramidite (623 mg, 0.73 mmol, 1.8 eq) are dissolved in anhydrous dichloromethane (15 ml). The solution is transferred under argon in a flask containing the poly(4-vinylpyridinium *p*-toluenesulfonate) (1.2 g, 4.0 mmol tos⁻, 10 eq) and is shaken for 6 h 20 min. Water (50 mL) is added to hydrolyze the remaining phosphoramidite.

15 After 1 h the resin is filtered off. The reaction is followed by reverse phase HPLC and ³¹P NMR. The yield is determined by HPLC. The desired dA-T-dG phosphite triester trimer (HPLC at 11.32 min; Area = 66%) is obtained with

100 % of yield compared to the 5'-OH-T-dG^{IBu}-3'-O-Lev cyanoethyl phosphorothioate triester (HPLC at 7.27 min; Area = 0%). The crude is a mixture of

15 5'-O-DMTr-dA^{Bz}-3'-cyanoethyl-phosphite-T-3'-cyanoethyl-thionophotriester-dG^{IBu}-3'-O-Lev trimer ³¹P NMR (CDCl₃) (d 140.97,

20 140.79, 140.40, 139.90, 67.89, 67.87, 67.83) and 5'-O-DMTr-dA^{Bz}-3'-cyanoethyl hydrogenophosphonate (d 8.12, 8.03).

Sulfurization: To a solution of 5'-O-DMTr-dA^{Bz}-3'-cyanoethyl-phosphite-T-3'-cyanoethyl-thionophotriester-dG^{IBu}-3'-O-Lev (0.4 mmol) in anhydrous dichloromethane is added AMBERLYST A26 tetrathionate form (1.12 g, 2.0 mmol S₄O₆²⁻, 5 eq.). The reaction mixture is shaken for 14 h. The reaction is followed by reverse phase HPLC and ³¹P NMR. The yield is determined by HPLC. After filtration of the resin the desired dA-T-dG phosphorothioate triester trimer (HPLC at 11.63 min; Area = 64 %) is obtained with 100 % of yield compared to the 5'-OH-T-dG^{IBu}-3'-O-Lev cyanoethyl phosphorothioate triester.

25 The crude is a mixture of 5'-O-DMTr-dA^{Bz}-T-dG^{IBu}-3'-O-Lev cyanoethyl phosphorothioate triester ³¹P NMR (CDCl₃) (d 68.05, 67.92, 67.84, 67.68) and 5'-O-DMTr-dA^{Bz}-3'-cyanoethyl hydrogenophosphonate (d 8.16, 7.98); MALDI-TOF MS (positive mode, trihydroxyacetophenone as matrix) [M-DMTr]⁺ m/z_{exp} = 1583.16, m/z_{calc} = 1582.53.

30 **Detritylation:** To a solution of 5'-O-DMTr-dA^{Bz}-T-dG^{IBu}-3'-O-Lev cyanoethyl phosphorothioate triester (0.4 mmol) in 60 ml CH₂Cl₂/CH₃OH (7/3) is added 4

ml (2.5 mmol, 6.3 eq.) of a solution of benzene sulfonic acid 10% in $\text{CH}_2\text{Cl}_2/\text{CH}_3\text{OH}$ (7/3). The solution is stirred 30 min at 0°C. The reaction is washed with 10 ml of a saturated solution of NaHCO_3 , the organic layer is separated, dried (MgSO_4) and evaporated. The crude product is dissolved in 10 mL dichloromethane and added to 50 mL diethylether at 0°C to give a white precipitate. Yield: 543 mg, 0.32 mmol, 80 %; ^{31}P NMR (CDCl_3) δ 67.94, 67.79, 67.72, 67.66, 67.58, 67.28, 67.14; MALDI-TOF MS (positive mode, trihydroxyacetophenone as matrix) $[\text{M}-\text{H}]^+$ m/z_{exp} = 1296.07, m/z_{calc} = 1296.22; HPLC (9.39 min; Area = 77%).

10 **Example 32**

Synthesis of the tetramer 5'-OH-dC^{Bz}-dG^{IBU}-T-T-3'-O-Lev cyanoethyl phosphorothioate triester.

15 **1st Coupling procedure** of 5'-O-DMTr-T-3'-cyanoethyl-phosphoramidite with 5'-OH-T-3'-O-Lev using the poly(4-vinylpyridinium *p*-toluenesulfonate) (Aldrich) providing the 5'-O-DMTr-T-T-3'-O-Lev cyanoethyl phosphite triester dimer:

20 5'-OH-T-3'-O-Lev (340 mg, 1.0 mmol) and 5'-O-DMTr-T-3'-cyanoethyl-phosphoramidite (1266 mg, 1.7 mmol, 1.7 eq) are dissolved in anhydrous dichloromethane (10 ml). The solution is transferred under argon in a flask containing the poly(4-vinylpyridinium *p*-toluenesulfonate) (3.0 g, 10 mmol tos⁻, 10 eq) and is shaken for 5 h 15 min. Water (50 mL) is added to hydrolyze the remaining phosphoramidite. After 1 h 15 min the resin is filtered off. The reaction is followed by reverse phase HPLC and ^{31}P NMR. The yield is determined by HPLC. The desired T-T phosphite triester dimer (HPLC at 11.14 min; Area = 25 71%) is obtained with 100% of yield compared to the 5'-OH-T-3'-O-Lev (HPLC at 5.49 min; Area = 0%). The crude is a mixture of 5'-O-DMTr-T-T-3'-O-Lev cyanoethyl phosphite triester ^{31}P NMR (CDCl_3) (δ 140.58, 140.31) and 5'-O-DMTr-T-3'-cyanoethyl hydrogenophosphonate (δ 8.10, 8.04).

30 **1st Sulfurization:** To a solution of 5'-O-DMTr-T-T-3'-O-Lev cyanoethyl phosphite triester dimer (1.0 mmol) in anhydrous dichloromethane is added AMBERLYST A26 tetrathionate form (3.89 g, 7.0 mmol $\text{S}_4\text{O}_6^{2-}$, 7 eq.). The reaction mixture is shaken for 20 h. The reaction is followed by reverse phase HPLC and ^{31}P NMR. The yield is determined by HPLC. After filtration of the resin the desired T-T phosphorothioate triester dimer (HPLC at 11.44 min; 35 Area = 75%) is obtained with 100% of yield compared to the 5'-OH-T-3'-O-Lev. The crude is a mixture of 5'-O-DMTr-T-T-3'-O-Lev cyanoethyl phos-

phorothioate ^{31}P NMR (CDCl_3) (δ 68.20, 68.14) and 5'-O-DMTr-T-3'-cyanoethyl hydrogenophosphonate (δ 8.11, 8.05).

1st Detritylation: To a solution of 5'-O-DMTr-T-T-3'-O-Lev cyanoethyl phosphorothioate triester (1.0 mmol) in 70 ml $\text{CH}_2\text{Cl}_2/\text{CH}_3\text{OH}$ (7/3) is added 4 ml (2.5 mmol, 2.5 eq.) of a solution of benzene sulfonic acid 10 % in $\text{CH}_2\text{Cl}_2/\text{CH}_3\text{OH}$ (7/3). The solution is stirred 40 min at 0°C. The reaction is washed with 10 ml of a saturated solution of NaHCO_3 , the organic layer is separated, dried (MgSO_4) and evaporated. The crude product is dissolved in 8 mL dichloromethane and added to 50 mL diethylether at 0°C to give a white precipitate. Yield: 764 mg, 0.99 mmol, 99%; ^{31}P NMR (CDCl_3) δ 67.87, 67.60; MALDI-TOF MS (positive mode, trihydroxyacetophenone as matrix) $[\text{M}-\text{H}]^+$ $m/z_{\text{exp}} = 713.95$, $m/z_{\text{calc}} = 714.66$; HPLC (7.70 min; Area = 88%).

2nd Coupling procedure of 5'-O-DMTr-dG^{IBu}-3'-cyanoethyl-phosphoramidite with 5'-OH-T-T-3'-O-Lev cyanoethyl phosphorothioate dimer using the poly(4-vinylpyridinium *p*-toluenesulfonate) (Aldrich) providing the 5'-O-DMTr-dG^{IBu}-3'-cyanoethyl-phosphite-T-3'-cyanoethyl-thionophosphotriester-T-3'-O-Lev trimer:

5'-OH-T-T-3'-O-Lev cyanoethyl phosphorothioate (764 mg, 0.99 mmol) and 5'-O-DMTr-dG^{IBu}-3'-cyanoethyl-phosphoramidite (1400 mg, 1.7 mmol, 1.7 eq) are dissolved in anhydrous dichloromethane (20 ml). The solution is transferred under argon in a flask containing the poly(4-vinylpyridinium *p*-toluenesulfonate) (3.0 g, 10 mmol tos⁻, 10 eq) and is shaken for 2 h 50 min. Water (50 mL) is added to hydrolyze the remaining phosphoramidite. After 1 h 20 min the resin is filtered off. The reaction is followed by reverse phase HPLC and ^{31}P NMR. The yield is determined by HPLC. The desired 5'-O-DMTr-dG^{IBu}-3'-cyanoethyl-phosphite-T-3'-cyanoethyl-thionophosphotriester-T-3'-O-Lev trimer (HPLC at 11.65 min; Area = 72%) is obtained with 100% of yield compared to the 5'-OH-T-T-3'-O-Lev cyanoethyl phosphorothioate (HPLC at 7.70 min; Area = 0%). The crude is a mixture of 5'-O-DMTr-dG^{IBu}-3'-cyanoethyl-phosphite-T-3'-cyanoethyl-thionophosphotriester-T-3'-O-Lev trimer ^{31}P NMR (CDCl_3) (δ 142.78, 142.67, 141.64, 141.50, 68.47, 68.39, 68.16, 67.93) and 5'-O-DMTr-dG^{IBu}-3'-cyanoethyl hydrogenophosphonate (δ 8.59, 8.05).

2nd Sulfurization: To a solution of 5'-O-DMTr-dG^{IBu}-3'-cyanoethyl-phosphite-T-3'-cyanoethyl-thionophosphotriester-T-3'-O-Lev trimer (0.99 mmol) in anhydrous dichloromethane is added AMBERLYST A26 tetrathionate form (2.78 g, 5.0 mmol $\text{S}_4\text{O}_6^{2-}$, 5 eq.). The reaction mixture is shaken for 18 h 45 min. The reaction is followed by reverse phase HPLC and ^{31}P NMR. The yield is de-

terminated by HPLC. After filtration of the resin the desired dG-T-T phosphorothioate triester trimer (HPLC at 11.66 min; Area = 58%) is obtained with 100% of yield compared to the 5'-OH-T-T-3'-O-Lev cyanoethyl phosphorothioate. The crude is a mixture of 5'-DMTr-dG^{IBu}-T-T-3'-O-Lev cyanoethyl phosphorothioate triester trimer ³¹P NMR (CDCl₃) (d 68.94, 68.43, 68.09, 67.93, 67.69, 67.34); MALDI-TOF MS (positive mode, trihydroxyacetophenone as matrix) [M-H]⁺ m/z_{exp} = 1484.81, m/z_{calc} = 1485.47 and 5'-O-DMTr-dG^{IBu}-3'-cyanoethyl hydrogenophosphonate (d 8.59, 8.52).

5 **2nd Detritylation:** To a solution of 5'-DMTr-dG^{IBu}-T-T-3'-O-Lev cyanoethyl phosphorothioate triester trimer (0.99 mmol) in 75 ml CH₂Cl₂/CH₃OH (7/3) is added 4 ml (2.5 mmol, 2.5 eq.) of a solution of benzene sulfonic acid 10 % in CH₂Cl₂/CH₃OH (7/3). The solution is stirred 40 min at 0°C. The reaction is washed with 10 ml of a saturated solution of NaHCO₃, the organic layer is separated, dried (MgSO₄) and evaporated. The crude product is dissolved in 8 mL dichloromethane and added to 50 mL diethylether at 0°C to give a white precipitate. Yield: 1257 mg, 0.78 mmol, 79%; ³¹P NMR (CDCl₃) d 68.32, 68.07, 68.01, 67.95, 67.86, 67.51, 67.25; MALDI-TOF MS (positive mode, trihydroxyacetophenone as matrix) [M-H]⁺ m/z_{exp} = 1182.12, m/z_{calc} = 1183.09; HPLC (8.94 min; Area = 79%).

10 20 **3rd Coupling procedure** of 5'-O-DMTr-dC^{Bz}-3'-cyanoethyl-phosphoramidite with 5'-OH-dG^{IBu}-T-T-3'-O-Lev cyanoethyl phosphorothioate triester trimer using the poly(4-vinylpyridinium *p*-toluenesulfonate) (Aldrich) providing the 5'-O-DMTr-dC^{Bz}-3'-cyanoethyl-phosphite-dG^{IBu}-cyanoethyl-thionophosphotriester-T-3'-cyanoethyl-thionophosphotriester-T-3'-O-Lev tetramer:

15 25 5'-OH-dG^{IBu}-T-T-3'-O-Lev cyanoethyl phosphorothioate triester trimer (1257 mg, 0.78 mmol) and 5'-O-DMTr-dC^{Bz}-3'-cyanoethyl-phosphoramidite (1420 mg, 1.7 mmol, 2.2 eq) are dissolved in anhydrous dichloromethane (20 mL). The solution is transferred under argon in a flask containing the poly(4-vinylpyridinium *p*-toluenesulfonate) (3.0 g, 10 mmol tos⁻, 12.8 eq) and is 30 shaken for 4 h 50 min. Water (100 mL) is added to hydrolyze the remaining phosphoramidite. After 20 min the resin is filtered off. The reaction is followed by reverse phase HPLC and ³¹P NMR. The yield is determined by HPLC. The desired 5'-O-DMTr-dC^{Bz}-3'-cyanoethyl-phosphite-dG^{IBu}-3'-cyanoethyl-thiono-phosphotriester-T-3'-cyanoethyl-thionophosphotriester-T-3'-O-Lev tetramer (HPLC at 12.04 min; Area = 79%) is obtained with 100% of yield compared to the 5'-OH-dG^{IBu}-T-T-3'-O-Lev cyanoethyl phosphorothioate triester trimer (HPLC at 8.94 min; Area = 0%). The crude is a mixture of 5'-O-DMTr-dC^{Bz}-3'-

cyanoethyl-phosphite-dG^{IBu}-3'-cyanoethyl-thionophosphotriester-T-3'-cyanoethyl-thionophosphotriester-T-3'-O-Lev tetramer ^{31}P NMR (CDCl_3) (d 141.01, 140.93, 140.05, 139.90, 68.50, 68.09, 68.04, 67.95) and 5'-O-DMTr-dC^{Bz}-3'-cyanoethyl hydrogenophosphonate (d 8.15).

5 **3rd Sulfurization:** To a solution of 5'-O-DMTr-dC^{Bz}-3'-cyanoethyl-phosphite-dG^{IBu}-3'-cyanoethyl-thionophosphotriester-T-3'-cyanoethyl-thionophosphotriester-T-3'-O-Lev trimer (0.78 mmol) in anhydrous dichloromethane is added AMBERLYST A26 tetrathionate form (2.78 g, 5.0 mmol $\text{S}_4\text{O}_6^{2-}$, 6.4 eq.). The reaction mixture is shaken for 3 h. The reaction is followed by reverse phase HPLC and ^{31}P NMR. The yield is determined by HPLC. After filtration of the resin the desired dC-dG-T-T phosphorothioate triester tetramer (HPLC at 121.18 min; Area = 73%) is obtained with 100% of yield compared to the 5'-OH-dG^{IBu}-T-T-3'-O-Lev cyanoethyl phosphorothioate triester trimer. The crude is a mixture of 5'-DMTr-dC^{Bz}-dG^{IBu}-T-T-3'-O-Lev cyanoethyl phosphorothioate triester tetramer ^{31}P NMR (CDCl_3) (d 68.51, 68.45, 68.22, 68.18, 68.10, 68.09, 67.70, 67.65); MALDI-TOF MS (positive mode, trihydroxyacetophenone as matrix) $[\text{M}-\text{H}]^+$ $m/z_{\text{exp}} = 1947.90$, $m/z_{\text{calc}} = 1947.89$ and 5'-O-DMTr-dC^{Bz}-3'-cyanoethyl hydrogenophosphonate (d 8.09).

20 **3rd Detritylation:** To a solution of 5'-DMTr-dC^{Bz}-dG^{IBu}-T-T-3'-O-Lev cyanoethyl phosphorothioate triester tetramer (0.78 mmol) in 80 ml $\text{CH}_2\text{Cl}_2/\text{CH}_3\text{OH}$ (7/3) is added 7 ml (4.4 mmol, 5.6 eq.) of a solution of benzene sulfonic acid 10 % in $\text{CH}_2\text{Cl}_2/\text{CH}_3\text{OH}$ (7/3). The solution is stirred 50 min at 0°C. The reaction is washed with 10 ml of a saturated solution of NaHCO_3 , the organic layer is separated, dried (MgSO_4) and evaporated. The crude product is dissolved in 25 1.2 mL $\text{CH}_2\text{Cl}_2/\text{CH}_3\text{OH}$ (2/1) and added to 100 mL diethylether at 0°C to give a white precipitate. Yield: 1334 mg, 0.53 mmol, 68%; ^{31}P NMR (CDCl_3) d 68.50, 68.41, 67.93, 67.86, 67.81, 67.74, 67.71, 67.64, 67.57, 67.51; MALDI-TOF MS (positive mode, trihydroxyacetophenone as matrix) $[\text{M}-\text{H}]^+$ $m/z_{\text{exp}} = 1645.24$, $m/z_{\text{calc}} = 1645.52$; HPLC (9.95 min; Area = 68%).

30 **Example 33**

Synthesis of the dimer 5'-OH-dC^{Bz}-dC^{Bz}-3'-O-TBDMS cyanoethyl phosphorothioate triester.

Coupling procedure of 5'-O-DMTr-dC^{Bz}-3'-cyanoethyl-phosphoramidite with 5'-OH-dC^{Bz}-3'-O-TBDMS using the poly(4-vinylpyridinium *p*-toluenesulfonate) (Aldrich):

35 5'-OH-dC^{Bz}-3'-O-TBDMS (100 mg, 0.22 mmol) and 5'-O-DMTr-dC^{Bz}-3'-

cyanoethyl-phosphoramidite (384 mg, 0.46 mmol, 2.1 eq) are dissolved in anhydrous acetonitrile (15 ml). The solution is transferred under argon in a flask containing the poly(4-vinylpyridinium *p*-toluenesulfonate) (690 mg, 2.3 mmol tos⁻, 10.3 eq) and is shaken for 6 h. The resin is filtered off. The reaction 5 is followed by ³¹P NMR. The yield is determined by ³¹P NMR. The desired dC-dC phosphite triester dimer is obtained with 100% of yield compared to the 5'-OH-dG^{IBu}-3'-O-TBDMS. The crude is a mixture of 5'-O-DMTr-dC^{Bz}-dC^{Bz}-3'-O-TBDMS cyanoethyl phosphite triester ³¹P NMR (CDCl₃) (d 141.06, 140.93) and 5'-O-DMTr-dC^{Bz}-3'-cyanoethyl hydrogenophosphonate (d 8.67).
10 **Sulfurization:** To a solution of 5'-O-DMTr-dC^{Bz}-dC^{Bz}-3'-O-TBDMS cyanoethyl phosphite triester dimer (0.22 mmol) in anhydrous acetonitrile is added AMBERLYST A26 tetrathionate form (620 mg, 1.2 mmol S₄O₆²⁻, 5.4 eq.). The reaction mixture is shaken for 65 h. The reaction is followed by ³¹P NMR. The yield is determined by ³¹P NMR. After filtration of the resin the desired dC-dC 15 phosphorothioate triester dimer is obtained with 100 % of yield compared to the 5'-OH-dC^{Bz}-3'-O-TBDMS. The crude is a mixture of 5'-O-DMTr-dC^{Bz}-dC^{Bz}-3'-O-TBDMS cyanoethyl phosphorothioate ³¹P NMR (CDCl₃) (d 68.24, 68.19) and 5'-O-DMTr-dC^{Bz}-3'-cyanoethyl hydrogenophosphonate (d 8.57).
20 **Detritylation:** To a solution of 5'-O-DMTr-dC^{Bz}-dC^{Bz}-3'-O-TBDMS cyanoethyl phosphorothioate triester (0.22 mmol) in 20 ml CH₂Cl₂/CH₃OH (7/3) is added 0.5 ml (0.3 mmol, 1.3 eq.) of a solution of benzene sulfonic acid 10% in CH₂Cl₂/CH₃OH (7/3). The solution is stirred 30 min at 0°C. Another 0.5 ml (0.3 mmol, 1.3 eq.) of a solution of benzene sulfonic acid 10% in CH₂Cl₂/CH₃OH (7/3) is added and the solution is stirred for 30 min. Another 0.7 ml (0.4 mmol, 1.8 eq.) of a solution of benzene sulfonic acid 10% in CH₂Cl₂/CH₃OH (7/3) is added and the solution is stirred for 30 min. The reaction is washed 25 with 5 ml of a saturated solution of NaHCO₃, the organic layer is separated, dried (Na₂SO₄), evaporated and purified on a silica gel column. The desired dimer dC-dC is eluted with CH₂Cl₂/CH₃OH (33/1). Yield: 106 mg, 0.1 mmol, 30 52%; ³¹P NMR (CDCl₃) d 67.92, 67.78; MALDI-TOF MS (positive mode, trihydroxyacetophenone as matrix) [M-H]⁺ m/z_{exp} = 908.47, m/z_{calc} = 909.02; HPLC (12.73 min; Area = 85%).

Example 34

35 *Synthesis of the dimer 5'-OH-dG^{IBu}-dA^{Bz}-3'-O-Lev cyanoethyl phosphorothioate triester.*

Coupling procedure of 5'-O-DMTr-dG^{IBu}-3'-cyanoethyl-phosphoramidite with

5'-OH-dA^{Bz}-3'-O-Lev using the poly(4-vinylpyridinium *p*-toluenesulfonate) (Aldrich):

5'-OH-dA^{Bz}-3'-O-Lev (2.235 g, 4.93 mmol) and 5'-O-DMTr-dG^{iBu}-3'-cyanoethyl-phosphoramidite (6.13 g, 7.43 mmol, 1.5 eq) are dissolved in anhydrous dichloromethane (100 ml). The solution is transferred under argon in a flask containing the poly(4-vinylpyridinium *p*-toluenesulfonate) (14.76 g, 49.3 mmol tos⁻, 10 eq) and is shaken for 2 h 45 min. Water (0.2 ml) is added and the mixture is shaken for 1 h 25 min. The resin is filtered off. The reaction is followed by reverse phase HPLC and ³¹P NMR. The yield is determined by HPLC.

10 The desired dG-dA phosphite triester dimer (HPLC at 11.69 min; Area = 65 %) is obtained with 100% of yield compared to the 5'-OH-dA^{Bz}-3'-O-Lev (HPLC at 7.20 min; Area = 0%). The crude is a mixture of 5'-O-DMTr-dG^{iBu}-dA^{Bz}-3'-O-Lev cyanoethyl phosphite triester ³¹P NMR (CDCl₃) (d 140.52, 140.20) and 5'-O-DMTr-dG^{iBu}-3'-cyanoethyl hydrogenophosphonate (d 8.59, 8.09).

15 **Sulfurization:** To a solution of 5'-O-DMTr-dG^{iBu}-dA^{Bz}-3'-O-Lev cyanoethyl phosphite triester dimer (4.93 mmol) in anhydrous dichloromethane is added AMBERLYST A26 tetrathionate form (19.7 g, 24.63 mmol S₄O₆²⁻, 5 eq.). The reaction mixture is shaken for 3 h 10 min. The reaction is followed by reverse phase HPLC and ³¹P NMR. The yield is determined by ³¹P NMR. After filtration 20 of the resin the desired dG-dA phosphorothioate triester dimer is obtained with 100 % of yield compared to the 5'-OH-dA^{Bz}-3'-O-Lev. The crude is a mixture of 5'-O-DMTr-dG^{iBu}-dA^{Bz}-3'-O-Lev cyanoethyl phosphorothioate ³¹P NMR (CDCl₃) (d 68.45, 67.73) and 5'-O-DMTr-dG^{iBu}-3'-cyanoethyl hydrogenophosphonate (d 8.60, 8.04).

25 **Detritylation:** To a solution of 5'-O-DMTr-dG^{iBu}-dA^{Bz}-3'-O-Lev cyanoethyl phosphorothioate triester (4.93 mmol) in 200 ml dichloromethane is added 50 ml methanol and 20 ml (12.6 mmol, 2.6 eq.) of a solution of benzene sulfonic acid 10% in CH₂Cl₂/CH₃OH (7/3). The solution is stirred 40 min at 0°C. Another 6 ml (3.8 mmol, 0.8 eq.) of a solution of benzene sulfonic acid 10% in 30 CH₂Cl₂/CH₃OH (7/3) is added and the solution is stirred for 15 min. Another 4 ml (2.5 mmol, 0.5 eq.) of a solution of benzene sulfonic acid 10 % in CH₂Cl₂/CH₃OH (7/3) is added and the solution is stirred for 15 min. The reaction is washed with 70 ml of a saturated solution of NaHCO₃, the organic layer is separated, dried (MgSO₄) and evaporated. The crude product is dissolved in 35 16 mL dichloromethane and added to 100 ml diethylether at 0°C to give a white precipitate. Yield: 4.28 mg, 3.8 mmol, 77%; ³¹P NMR (CDCl₃) d 68.07, 67.80; MALDI-TOF MS (positive mode, trihydroxyacetophenone as matrix) [M-

$[M-H]^+$ $m/z_{exp} = 923.08$, $m/z_{calc} = 922.89$; HPLC (8.90 min and 9.07 min; Area = 70%). After complete deprotection with ammonia solution (28% NH₃ in water, 14 h) MALDI-TOF MS (positive mode, trihydroxyacetophenone as matrix) $[M-H]^+$ $m/z_{exp} = 597.57$, $m/z_{calc} = 596.51$; HPLC (8.45 min and 8.77 min; Area = 5 82%).

Example 35

Synthesis of the dimer 5'-DMTr-O-dC^{Bz}-dA^{Bz}-3'-OH cyanoethyl phosphorothioate triester.

Coupling procedure of 5'-O-DMTr-dC^{Bz}-3'-cyanoethyl-phosphoramidite with 10 5'-OH-dA^{Bz}-3'-O-Lev using the poly(4-vinylpyridinium *p*-toluenesulfonate) (Aldrich):

5'-OH-dA^{Bz}-3'-O-Lev (200 mg, 0.44 mmol) and 5'-O-DMTr-dC^{Bz}-3'-cyanoethyl-phosphoramidite (626 mg, 0.75 mmol, 1.7 eq) are dissolved in anhydrous dichloromethane (10 ml). The solution is transferred under argon in a flask 15 containing the poly(4-vinylpyridinium *p*-toluenesulfonate) (1.3 g, 3 mmol tos⁻, 6.8 eq) and is shaken for 8 h. The resin is filtered off. The reaction is followed by reverse phase HPLC and ³¹P NMR. The yield is determined by HPLC. The desired dC-dA phosphite triester dimer (HPLC at 13.13 min; Area = 63%) is obtained with 100% of yield compared to the 5'-OH-dA^{Bz}-3'-O-Lev (HPLC at 20 7.39 min; Area = 0%). The crude is a mixture of 5'-O-DMTr-dG^{Bz}-dA^{Bz}-3'-O-Lev cyanoethyl phosphite triester ³¹P NMR (CDCl₃) (d 140.68, 140.58) and 5'-O-DMTr-dC^{Bz}-3'-cyanoethyl hydrogenophosphonate (d 8.04, 8.02).

Sulfurization: To a solution of 5'-O-DMTr-dC^{Bz}-dA^{Bz}-3'-O-Lev cyanoethyl phosphite triester dimer (0.44 mmol) in anhydrous dichloromethane is added 25 AMBERLYST A26 tetrathionate form (2.5 g, 4.38 mmol S₄O₆²⁻, 9.9 eq.). The reaction mixture is shaken for 10 h. The reaction is followed by reverse phase HPLC and ³¹P NMR. The yield is determined by ³¹P NMR. After filtration of the resin the desired dC-dA phosphorothioate triester dimer is obtained with 100% of yield compared to the 5'-OH-dA^{Bz}-3'-O-Lev. The Solvent is removed under 30 reduced pressure. The crude is a mixture of 5'-O-DMTr-dC^{Bz}-dA^{Bz}-3'-O-Lev cyanoethyl phosphorothioate ³¹P NMR (CDCl₃) (d 68.33, 68.30) and 5'-O-DMTr-dC^{Bz}-3'-cyanoethyl hydrogenophosphonate (d 8.04, 8.02).

Deprotection of the levulinyl group: The 5'-O-DMTr-dC^{Bz}-dA^{Bz}-3'-O-Lev cyanoethyl phosphorothioate triester (0.44 mmol) is dissolved in 16 ml pyridine and 4 ml acetic acid. AMBERLYST 15 hydrazine form (1 g, 3.91 mmol N₂H₅⁻, 8.7 eq.) is added and the solution is shaken for 1 h 30 min. The reaction

is followed by reverse phase HPLC. The yield is determined by reverse phase HPLC. After filtration of the resin the desired dC-dA phosphorothioate triester dimer is obtained with 100 % of yield compared to the 5'-OH-dA^{Bz}-3'-O-Lev. The Solvent is removed under reduced pressure. The crude is a mixture of 5'-O-DMTr-dC^{Bz}-dA^{Bz}-3'-OH cyanoethyl phosphorothioate HPLC (12.24 min and 12.45 min; Area = 66%) and 5'-O-DMTr-dC^{Bz}-3'-cyanoethyl hydrogenophosphonate HPLC (10.71 min and 10.82 min; Area = 34 %). MALDI-TOF MS (positive mode, trihydroxyacetophenone as matrix) [M-H]⁺ m/z_{exp} = 1120.23, m/z_{calc} = 1121.16.

10 SYNTHESES OF RESINS

Example 36

Synthesis of AMBERLYST A26 periodate form.

10 g commercial Amberlyst A26 hydroxide form (Rohm & Haas) is washed twice with 20 ml methanol and twice with 20 ml dichloromethane and dried in 15 vacuum. Potassium tetrathionate (10 g, 47 mmol, 1.4 eq.) is dissolved in 300 ml deionized water. The solution is added to the resin and shaken for 17 hours. The solution is filtered off. Another time Potassium tetrathionate (10 g, 47 mmol, 1.4 eq.) is dissolved in 200 ml deionized water. The solution is added to the resin and shaken for 6 hours. The solution is filtered off. The 20 resin is washed with 1 l deionized water, twice with 30 ml methanol and twice with 30 ml dichloromethane and dried under reduced pressure for 3 hours to give 8.2 g of solid-supported periodate. The reagents loading was determined by elemental analysis, giving a value of 27.16% for iodine (3.40% for nitrogen and 40.20% for carbon. Loading: 2.14 mmol IO₄⁻ per gram of resin. The resin 25 can be recycled applying the same protocol. Comparable resins are commercially available.

Example 37

Synthesis of AMBERLYST 15 hydrazine form.

5 g commercial Amberlyst 15 H⁺ form (Aldrich) is washed successively with 20 ml hydrochloric acid and with 500 ml deionized water. Hydrazine (4.38 g, 87.5 mmol, 3.8 eq.) is dissolved in 100 ml deionized water. The solution is added to the resin and shaken for 16 hours. The solution is filtered off. The resin is washed successively with 500 ml deionized water, 50 ml methanol and with 50 ml dichloromethane and dried under reduced pressure for 3 hours to give 5.2 g of solid-supported hydrazine. The reagents loading was determined by ele-

mental analysis, giving a value of 10.94 % for nitrogen (12.37% for sulfur and 44.19% for carbon. Loading: 3.91 mmol N_2H_5^+ per gram of resin.

Example 38

Recycling of poly(4-vinylpyridinium p-toluenesulfonate)

5 Used poly(4-vinylpyridinium p-toluenesulfonate) (20 g) is washed successively for one hour each with acetonitrile (100 ml), dichloromethane (100 ml) and methanol (100 ml). Then the resin is added to a solution of *p*-toluene sulfonic acid (40 g, 0.23 mol) in methanol (400 ml) and shaken for 21 h. The solution is filtered off and the resin is washed with methanol (150 ml) and dichloromethane (150 ml) and dried at 80°C under vacuum over P_2O_5 for 8 h.

10 The reagents loading was determined by elemental analysis, giving a value of 10.73% for sulfur and 4.90% for nitrogen. Loading: 3.35 mmol tos^- per gram of resin.

SYNTHESIS OF PHOSPHODIESTER OLIGOMERS

15 FORMATION OF THE PHOSPHATE TRIESTER BRIDGE

In this part, we focus on the formation of natural phosphodiester oligomers. The coupling of the phosphoramidite nucleotide and of the 5'-OH nucleoside was performed with the resin polyvinyl pyridinium *p*-toluene sulfonate (PVP) commercially available from ALDRICH. The oxidation of the phosphite triester linkage was achieved with the resin polystyrylmethyltrimethylammonium meta-periodate ($\text{PS-N}(\text{CH}_3)_3^+ \text{IO}_4^-$) commercially available from NOVABIOCHEM. Then, the detritylation step was performed in solution with BSA. The purification was an extraction in dichloromethane followed by a precipitation in ether.

Example 39

25 *Synthesis of the dimer 5'-OH-T-T-3'-O-Lev cyanoethyl phosphate triester.*

Coupling procedure of 5'-O-DMTr-T-3'-cyanoethyl phosphoramidite with 5'-OH-T-3'-O-Lev using the PVP resin.

A solution of 5'-OH-T-3'-O-Lev (170 mg, 0.5 mmol) and 5'-O-DMTr-T-3'-cyanoethyl phosphoramidite (745 mg, 1 mmol, 2 eq) in anhydrous acetonitrile (15 ml) is added to PVP resin (1.5 g, 5 mmol pyrH^+ , 10 eq). The reaction is followed by reverse phase HPLC. After 5h the reaction is complete. The desired dimer 5'-O-DMTr-T-T-3'-O-Lev cyanoethyl phosphite triester is characterized by ^{31}P NMR. The crude is a mixture of 5'-O-DMTr-T-T-3'-O-Lev cyanoethyl phosphite triester (δ 140.62, 140.48) and of 5'-O-DMTr-T-3'-cyanoethyl hy-

drogenophosphonate (d 8.81, 8.76).

Oxidation: The PVP resin is filtered off and the resulting solution is added to PS-N(CH₃)₃⁺ IO₄⁻ (1 g, 2.5 mmol IO₄⁻, 5 eq.). The reaction is followed by ³¹P NMR and by reverse phase HPLC. The reaction is complete after 45 min. The

5 desired dimer 5'-O-DMTr-T-T-3'-O-Lev cyanoethyl phosphate triester is characterized by ³¹P NMR. The crude is a mixture of 5'-O-DMTr-T-3'-cyanoethyl phosphate diester (d -2.80), 5'-O-DMTr-T-T-3'-O-Lev cyanoethyl phosphate triester (d -1.48, -1.63), 5'-O-DMTr-T-3'-cyanoethyl hydrogenophosphonate (d 8.69, 8.64).

10 **Detritylation:** The PS-N(CH₃)₃⁺ IO₄⁻ is filtered off and the solvent are evaporated. The crude is dissolved in 8ml of CH₂Cl₂/CH₃OH (7/3) and cooled in an ice bath. To this solution is added 2 ml of a solution of benzene sulfonic acid 10% in CH₂Cl₂/CH₃OH (7/3). The solution is stirred 45 min at 0°C. The reaction is stopped with 20 ml of a saturated solution of NaHCO₃. The aqueous phase is

15 extracted three times with dichloromethane. The organic layer is separated, dried (Na₂SO₄) and evaporated under reduce pressure. The residue is dissolved in 5ml of CH₂Cl₂/MeOH (4/1) and added to 50ml of cooled diethyl ether drop by drop with a strong stirring. The mixture is centrifuged for 45 min and the supernatant is eliminated. The desired 5'-OH-T-T-3'-O-Lev cyanoethyl

20 phosphate triester dimer is obtained with a yield of 75.4% (calculated: 91% per step) compared to the 5'-OH-T-3'-O-Lev. ³¹P NMR (CD₃CN) d -1.67, -1.72. MALDI-TOF MS (positive mode, trihydroxyacetophenone as matrix) [M+H]⁺ m/z_{exp} = 700.42, m/z_{calc} = 698.60. The spectrophotometric purity (91%) is determined by HPLC at 260 nm.

25 **Example 40**

Synthesis of the trimer 5'-OH-G^{iBu}-T-T-3'-O-Lev cyanoethyl phosphate triester.

Coupling procedure of 5'-O-DMTr-G^{iBu}-3'-cyanoethyl phosphoramidite with 5'-OH-T-T-3'-O-Lev dimer using the PVP resin.

30 A solution of 5'-OH-T-T-3'-O-Lev (263 mg, 377 mmol) and 5'-O-DMTr-G^{iBu}-3'-cyanoethyl phosphoramidite (623 mg, 754 mmol, 2 eq) in anhydrous acetonitrile (15 ml) is added to PVP resin (1.1 g, 3.8 mmol pyrH⁺, 10 eq). The reaction is followed by reverse phase HPLC. After 3h 30min the reaction is complete. The desired trimer 5'-O-DMTr-G^{iBu}-T-T-3'-O-Lev is characterized by ³¹P NMR. The crude is a mixture of 5'-O-DMTr-G^{iBu}-T-T-3'-O-Lev trimer (phosphite linkage d 141.56, 141.50, 141.44, 141.39, 141.13, 141.05 ; phosphate

35

triester linkage d -1.35, -1.44, -1.52, -1.57) and of 5'-O-DMTr-G^{IBu}-3'-cyanoethyl hydrogenophosphonate (d 9.03, 8.84).

Oxidation: The PVP resin is filtered off and the resulting solution is added to PS-N(CH₃)₃⁺ IO₄⁻ (0.75 g, 1.9 mmol IO₄⁻, 5 eq.). The reaction is followed by ³¹P NMR and by reverse phase HPLC. The reaction is complete after 45 min. The desired dimer 5'-O-DMTr-G^{IBu}-T-T-3'-O-Lev cyanoethyl phosphate triester is characterized by ³¹P NMR. The crude is a mixture of 5'-O-DMTr-G^{IBu}-3'-cyanoethyl phosphate diester (d -2.52), 5'-O-DMTr-G^{IBu}-T-T-3'-O-Lev cyanoethyl phosphate triester (d -1.23, -1.35, -1.43, -1.50, -1.55), 5'-O-DMTr-T-3'-cyanoethyl hydrogenophosphonate (d 9.09, 8.90).

Detritylation: The PS-N(CH₃)₃⁺ IO₄⁻ is filtered off and the solvent are evaporated. The crude is dissolved in 8ml of CH₂Cl₂/CH₃OH (7/3) and cooled in an ice bath. To this solution is added 2 ml of a solution of benzene sulfonic acid 10% in CH₂Cl₂/CH₃OH (7/3). The solution is stirred 45 min at 0°C. The reaction is stopped with 20 ml of a saturated solution of NaHCO₃. The aqueous phase is extracted three times with dichloromethane. The organic layer is separated, dried (Na₂SO₄) and evaporated under reduce pressure. The residue is dissolved in 5ml of CH₂Cl₂/MeOH (4/1) and added to 50ml of cooled diethyl ether drop by drop with a strong stirring. The mixture is centrifuged for 45 min and the supernatant is eliminated. The desired 5'-OH-G^{IBu}-T-T-3'-O-Lev cyanoethyl phosphate triester trimer is obtained with a yield of 37% (calculated: 72 % per step) compared to the 5'-OH-T-T-3'-O-Lev. ³¹P NMR (CD₃CN) d -1.59, -1.68, -1.71, -1.75. MALDI-TOF MS (positive mode, trihydroxyacetophenone as matrix) [M+H]⁺ m/z_{exp} = 1149.60, m/z_{calc} = 1150.96. The spectrophotometric purity (87%) is determined by HPLC at 260 nm.

This low yield is due to the low solubility of the detritylated trimer in dichloromethane, acetonitrile. The trimer is soluble in methanol, and DMF.

Example 41

Synthesis of the dimer 5'-OH-T-A^{Bz}-3'-O-Lev cyanoethyl phosphate triester.

Coupling procedure of 5'-O-DMTr-T-3'-cyanoethyl phosphoramidite with 5'-OH-A^{Bz}-3'-O-Lev using the PVP resin.

A solution of 5'-OH-A^{Bz}-3'-O-Lev (453 mg, 1 mmol) and 5'-O-DMTr-T-3'-cyanoethyl phosphoramidite (1.49 g, 2 mmol, 2 eq) in anhydrous acetonitrile (20 ml) is added to PVP resin (3 g, 10 mmol pyrH⁺, 10 eq). The reaction is followed by reverse phase HPLC. After 5h the reaction is complete. The desired dimer 5'-O-DMTr-T-A^{Bz}-3'-O-Lev cyanoethyl phosphite triester is characterized

by ^{31}P NMR. The crude is a mixture of 5'-O-DMTr-T-A^{Bz}-3'-O-Lev cyanoethyl phosphite triester (d 140.48, 140.30) and of 5'-O-DMTr-T-3'-cyanoethyl hydrogenophosphonate (d 8.76, 8.71).

Oxidation: The PVP resin is filtered off and the resulting solution is added to PS-N(CH₃)₃⁺ IO₄⁻ (2 g, 5 mmol IO₄⁻, 5 eq.). The reaction is followed by ^{31}P NMR and by reverse phase HPLC. The reaction is complete after 15 min. The desired dimer 5'-O-DMTr-T-A^{Bz}-3'-O-Lev cyanoethyl phosphate triester is characterized by ^{31}P NMR. The crude is a mixture of 5'-O-DMTr-T-3'- cyanoethyl phosphate diester (^{31}P NMR (CD₃CN) d -3.01), 5'-O-DMTr-T-A^{Bz}-3'-O-Lev cyanoethyl phosphate triester (d -1.58, -1.80), 5'-O-DMTr-T-3'-cyanoethyl hydrogenophosphonate (d 8.76, 8.71).

Detritylation: The PS-N(CH₃)₃⁺ IO₄⁻ is filtered off and the solvent are evaporated. The crude is dissolved in 16 ml of CH₂Cl₂/CH₃OH (7/3) and cooled in an ice bath. To this solution is added 4 ml of a solution of benzene sulfonic acid 10% in CH₂Cl₂/CH₃OH (7/3). The solution is stirred 45 min at 0°C. The reaction is stopped with 30 ml of a saturated solution of NaHCO₃. The aqueous phase is extracted three times with dichloromethane. The organic layer is separated, dried (Na₂SO₄) and evaporated under reduce pressure. The residue is dissolved in 10 ml of CH₂Cl₂/MeOH (4/1) and added to 100 ml of cooled diethyl ether drop by drop with a strong stirring. The mixture is centrifuged for 45 min and the supernatant is eliminated. The desired 5'-OH-T-A^{Bz}-3'-O-Lev cyanoethyl phosphate triester dimer is obtained with a yield of 73 % (calculated: 90% per step) compared to the 5'-OH-T-3'-O-Lev. ^{31}P NMR (CD₃CN) d -1.77. MALDI-TOF MS (positive mode, trihydroxyacetophenone as matrix) [M+H]⁺ m/z_{exp} = 811.72, m/z_{calc} = 810.45. The spectrophotometric purity (96%) is determined by HPLC at 260 nm.

Example 42

Synthesis of the trimer 5'-OH-C^{Bz}-T-A^{Bz}-3'-O-Lev cyanoethyl phosphate triester.

30 **Coupling procedure** of 5'-O-DMTr-C^{Bz}-3'-cyanoethyl phosphoramidite with 5'-OH-T-A^{Bz}-3'-O-Lev using the PVP resin.

A solution of 5'-OH-T-A^{Bz}-3'-O-Lev (618 mg, 0.76 mmol) and 5'-O-DMTr-C^{Bz}-3'-cyanoethyl phosphoramidite (1.27 g, 1.52 mmol, 2 eq) in anhydrous acetonitrile (25 ml) and anhydrous DMF (2.5 ml) is added to PVP resin (2.3 g, 7.6 mmol pyrH⁺, 10 eq). The reaction is followed by reverse phase HPLC. After 2h30 the reaction is complete. The desired trimer 5'-O-DMTr-C^{Bz}-A^{Bz}-T-3'-O-

Lev cyanoethyl phosphite triester is characterized by ^{31}P NMR. The crude is a mixture of 5'-O-DMTr-C^{Bz}-A^{Bz}-T-3'-O-Lev trimer (phosphite triester linkage d 140.76, 140.65, 140.09, 140.03 ; phosphate triester linkage d -1.53, -1.57) and of 5'-O-DMTr-C^{Bz}-3'-cyanoethyl hydrogenophosphonate (d 8.73).

5 **Oxidation:** The PVP resin is filtered off and the resulting solution is added to PS-N(CH₃)₃⁺ IO₄⁻ (1.52 g, 3.8 mmol IO₄⁻, 5 eq.). The reaction is followed by ^{31}P NMR and by reverse phase HPLC. The reaction is complete after 15 min. The desired trimer 5'-O-DMTr-C^{Bz}-T-A^{Bz}-3'-O-Lev cyanoethyl phosphate triester is characterized by ^{31}P NMR. The crude is a mixture of 5'-O-DMTr-C^{Bz}-T-A^{Bz}-3'-O-Lev cyanoethyl phosphate triester (d -1.54, -1.59, -162, -1.72), 5'-O-DMTr-C^{Bz}-3'-cyanoethyl hydrogenophosphonate (d 8.74).

10

15 **Detritylation:** The PS-N(CH₃)₃⁺ IO₄⁻ is filtered off and the solvent are evaporated. The crude is dissolved in 32 ml of CH₂Cl₂/CH₃OH (7/3) and cooled in an ice bath. To this solution is added 8 ml of a solution of benzene sulfonic acid 10% in CH₂Cl₂/CH₃OH (7/3). The solution is stirred 1 h at 0°C. The reaction is stopped with 40 ml of a saturated solution of NaHCO₃. The aqueous phase is extracted three times with dichloromethane. The organic layer is washed with an aqueous solution of Na₂S₂O₃ 0.2 M. The organic layer is separated, dried (Na₂SO₄) and evaporated under reduce pressure. The residue is dissolved in 20 10 ml of CH₂Cl₂ and added to 100 ml of cooled diethyl ether drop by drop with a strong stirring. The mixture is centrifuged for 45 min and the supernatant is eliminated. The desired 5'-OH-C^{Bz}-T-A^{Bz}-3'-O-Lev cyanoethyl phosphate triester trimer is obtained with a yield of 90% (calculated: 96% per step) compared to the dimer 5'-OH-T-A^{Bz}-3'-O-Lev. ^{31}P NMR (CD₃CN) d -1.75, -1.79, -1.87, -1.91. MALDI-TOF MS (positive mode, trihydroxyacetophenone as matrix) [M+H]⁺ m/z_{exp} = 1257.53, m/z_{calc} = 1258.08. The spectrophotometric purity (89%) is determined by HPLC at 260 nm.

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Example 43

30 *Synthesis of the tetramer 5'-OH-G^{IBu}-C^{Bz}-T-A^{Bz}-3'-O-Lev cyanoethyl phosphate triester.*

Coupling procedure of 5'-O-DMTr-G^{IBu}-3'-cyanoethyl phosphoramidite with 5'-OH-C^{Bz}-T-A^{Bz}-3'-O-Lev using the PVP resin.

A solution of 5'-OH-C^{Bz}-T-A^{Bz}-3'-O-Lev (866 mg, 0.69 mmol) and 5'-O-DMTr-G^{IBu}-3'-cyanoethyl phosphoramidite (1.14 g, 1.38 mmol, 2 eq) in anhydrous 35 acetonitrile (25 ml) and anhydrous DMF (2.5 ml) is added to PVP resin (2.1 g, 6.9 mmol pyrH⁺, 10 eq). The reaction is followed by reverse phase HPLC. After

3h the reaction is complete. The desired tetramer 5'-O-DMTr-G^{IBu}-C^{Bz}-A^{Bz}-T-3'-O-Lev is characterized by ³¹P NMR. The crude is a mixture of 5'-O-DMTr-G^{IBu}-C^{Bz}-A^{Bz}-T-3'-O-Lev tetramer (phosphite triester linkage d 141.86, 141.82, 141.76, 141.61, 140.69, 140.66, 140.61 ; phosphate triester linkage d -1.53, -1.58, -1.61, -1.64, -1.71, -1.82) and of 5'-O-DMTr-G^{IBu}-3'-cyanoethyl hydrogenophosphonate (d 9.01, 8.84).

Oxidation: The PVP resin is filtered off and the resulting solution is added to PS-N(CH₃)₃⁺ IO₄⁻ (1.38 g, 3.45 mmol IO₄⁻, 5 eq.). The reaction is followed by ³¹P NMR and by reverse phase HPLC. The reaction is complete after 45 min.

10 The desired tetramer 5'-O-DMTr-G^{IBu}-C^{Bz}-T-A^{Bz}-3'-O-Lev cyanoethyl phosphate triester is characterized by ³¹P NMR. The crude is a mixture of 5'-O-DMTr-G^{IBu}-3'- cyanoethyl phosphate diester (³¹P NMR (CD₃CN) d -2.69), 5'-O-DMTr-G^{IBu}-C^{Bz}-T-A^{Bz}-3'-O-Lev cyanoethyl phosphate triester (d -1.38, -1.43, -1.53, -1.60, -1.64), 5'-O-DMTr-C^{Bz}-3'-cyanoethyl hydrogenophosphonate (d 9.02, 8.38).

15 **Detritylation:** The PS-N(CH₃)₃⁺ IO₄⁻ is filtered off and the solvent are evaporated. The crude is dissolved in 32 ml of CH₂Cl₂/CH₃OH (7/3) and cooled in an ice bath. To this solution is added 8 ml of a solution of benzene sulfonic acid 10 % in CH₂Cl₂/CH₃OH (7/3). The solution is stirred 1 h 15 at 0°C. The reaction is stopped with 40 ml of a saturated solution of NaHCO₃. The aqueous 20 phase is extracted three times with dichloromethane. The organic layer is washed with an aqueous solution of Na₂S₂O₃ 0.2 M. The organic layer is separated, dried (Na₂SO₄) and evaporated under reduce pressure. The residue is dissolved in 4 ml of CH₂Cl₂ and added to 100 ml of cooled diethyl ether drop by drop with a strong stirring. The mixture is centrifuged for 45 min and the supernatant is eliminated. The desired 5'-OH-G^{IBu}-C^{Bz}-T-A^{Bz}-3'-O-Lev cyanoethyl phosphate triester tetramer is obtained with a yield of 83% (calculated: 94% 25 per step) compared to the trimer 5'-OH-C^{Bz}-T-A^{Bz}-3'-O-Lev. ³¹P NMR (CD₃CN) d -1.59, -1.69, -1.81. MALDI-TOF MS (positive mode, trihydroxyacetophenone as matrix) [M+H]⁺ m/z_{exp} = 1708.44, m/z_{calc} = 1710.45. The spectrophotometric purity (80%) is determined by HPLC at 260 nm.

Example 44

Synthesis of the pentamer 5'-OH-A^{Bz}-G^{IBu}-C^{Bz}-T-A^{Bz}-3'-O-Lev cyanoethyl phosphate triester.

Coupling procedure of 5'-O-DMTr-A^{Bz}-3'-cyanoethyl phosphoramidite with 35 5'-OH-G^{IBu}-C^{Bz}-T-A^{Bz}-3'-O-Lev using the PVP resin.

A solution of 5'-OH-G^{IBu}-C^{Bz}-T-A^{Bz}-3'-O-Lev (982 mg, 0.57 mmol) and 5'-O-

DMTr-A^{Bz}-3'-cyanoethyl phosphoramidite (1.15 g, 1.15 mmol, 2 eq) in anhydrous acetonitrile (20 ml) and anhydrous DMF (2.5 ml) is added to PVP resin (1.7 g, 5.7 mmol pyrH⁺, 10 eq). The reaction is followed by reverse phase HPLC. After 3h the reaction is complete. The desired pentamer 5'-O-DMTr-A^{Bz}-G^{tBu}-C^{Bz}-A^{Bz}-T-3'-O-Lev is characterized by ³¹P NMR. The crude is a mixture of 5'-O-DMTr-A^{Bz}-G^{tBu}-C^{Bz}-A^{Bz}-T-3'-O-Lev pentamer (phosphite triester linkage d 141.00, 140.78, 140.68, 140.16, 139.94 ; phosphate triester linkage d -1.36, -1.42, -1.46, -1.52, -1.57, -1.67, -1.70, -1.82) and of 5'-O-DMTr-A^{Bz}-3'-cyanoethyl hydrogenophosphonate (d 8.76, 8.71).

5 **Oxidation:** The PVP resin is filtered off and the resulting solution is added to PS-N(CH₃)₃⁺ IO₄⁻ (1.2 g, 2.87 mmol IO₄⁻, 5 eq.). The reaction is followed by ³¹P NMR and by reverse phase HPLC. The reaction is complete after 45 min. The desired pentamer 5'-O-DMTr-A^{Bz}-G^{tBu}-C^{Bz}-T-A^{Bz}-3'-O-Lev cyanoethyl phosphate triester is characterized by ³¹P NMR. The crude is a mixture of 5'-O-DMTr-A^{Bz}-3'-cyanoethyl phosphate diester (³¹P NMR (CD₃CN) d -2.67), 5'-O-DMTr-A^{Bz}-G^{tBu}-C^{Bz}-T-A^{Bz}-3'-O-Lev cyanoethyl phosphate triester (d -1.24, -1.39, -1.54, -1.66, -1.71), 5'-O-DMTr-A^{Bz}-3'-cyanoethyl hydrogenophosphonate (d 8.82).

10 **Detritylation:** The PS-N(CH₃)₃⁺ IO₄⁻ is filtered off and the solvent are evaporated. The crude is dissolved in 50 ml of CH₂Cl₂, the solution is washed with 50 ml of an aqueous solution of Na₂S₂O₃ 0.2 M. The organic layer is separated, dried (Na₂SO₄) and evaporated under reduce pressure. The crude is dissolved in 16 ml of CH₂Cl₂/CH₃OH (7/3) and cooled in an ice bath. To this solution is added 4 ml of a solution of benzene sulfonic acid 10 % in CH₂Cl₂/CH₃OH (7/3). The solution is stirred 45 min at 0°C. 70 ml of CH₂Cl₂ and 10 ml of pyridine are added to the solution. The reaction is stopped with 70 ml of a saturated solution of NaHCO₃. The aqueous phase is extracted three times with 30 ml of CH₂Cl₂ and 5 ml of pyridine. The organic layer is separated, dried (Na₂SO₄) and evaporated under reduce pressure. The residue is dissolved in 5 ml of CH₂Cl₂/MeOH (4/1) and added to 100 ml of cooled diethyl ether drop by drop with a strong stirring. The mixture is centrifuged for 45 min and the supernatant is eliminated. The desired 5'-OH-A^{Bz}-G^{tBu}-C^{Bz}-T-A^{Bz}-3'-O-Lev cyanoethyl phosphate triester pentamer is obtained with a yield of 85% (calculated: 95 % per step) compared to the tetramer 5'-OH-G^{tBu}-C^{Bz}-T-A^{Bz}-3'-O-Lev. ³¹P NMR (CD₃CN) d -1.35, -1.42, -1.55, -1.63. MALDI-TOF MS (positive mode, trihydroxyacetophenone as matrix) [M+H]⁺ m/z_{exp} = 2179.40, m/z_{calc} = 2180.83. The spectrophotometric purity (84 %) is determined by HPLC at 260 nm.

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Final deprotection of the pentamere :

20 mg (9 mmol) of the 5'-OH-A^{Bz}-G^{IBu}-C^{Bz}-T-A^{Bz}-3'-O-Lev cyanoethyl phosphate triester pentamer is dissolved in 5 ml of aqueous ammonia solution (30%). After 16 h at 55°C, the ammonia is evaporated. ³¹P NMR (D₂O) δ 0.26, 5 0.04, -0.03, -0.09. MALDI-TOF MS (negative mode, trihydroxyacetophenone as matrix) [M+H]⁻ m/z_{exp} = 1486.29, m/z_{calc} = 1486.03. The spectrophotometric purity (74 %) is determined by HPLC at 260 nm.

H-PHOSPHONATE SYNTHESIS**Example 45****10 Synthesis of the dimer 5'-O-DMTr-dG^{IBu}-T-3'-O-Lev H-phosphonate**

A solution of 5'-OH-T-3'-O-Lev (42.5 mg, 0.125 mmol) and of 5'-O-DMTr-dG^{IBu}-H-phosphonate TEA salt (120.7 mg, 0.150 mmol, 1.2 eq) in 2.0 ml of CH₂Cl₂/py (1:1) is added to polystyrene-bound acid chloride (430.0 mg, 2.1 mmol/g, 6.6 eq) that is suspended in 3.0 ml of the same solvent. The mixture 15 is shaken for 1h 30 min at room temperature until the disappearance of the monomers. The reaction is monitored by reverse phase HPLC. The resin is filtered, washed with CH₂Cl₂. The pyridinium salt present in solution is removed by aqueous extraction and the aqueous phase is washed twice with CH₂Cl₂. The organic fractions are collected, the solvent is evaporated and the pyridine 20 is eliminated by coevaporation with toluene. The isolated product is dried under vacuum. Yield 70%.

³¹P NMR (CD₂Cl₂) δ 10.20, 8.99 ppm.

MALDI-TOF MS (positive mode, trihydroxyacetophenone as matrix) [M+H]⁺ m/z_{exp} = 1025.72, m/z_{calc} = 1027.02.

25 The spectrophotometrical purity determined by HPLC is 98%.

Example 46**Synthesis of the dimer 5'-O-DMTr-dG^{IBu}-dC^{Bz}-3'-O-Lev H-phosphonate**

A solution of 5'-OH-dC^{Bz}-3'-O-Lev (53.7 mg, 0.125 mmol) and of 5'-O-DMTr-dG^{IBu}-H-phosphonate TEA salt (120.7 mg, 0.150 mmol, 1.2 eq) in 2.0 ml of CH₂Cl₂/py (1:1) is added to polystyrene-bound acid chloride (430.0 mg, 2.1 mmol/g, 6.6 eq) that is suspended in 3.0 ml of the same solvent. The mixture 30 is shaken for 1h 30 min at room temperature until the disappearance of the monomers. The reaction is monitored by reverse phase HPLC. The resin is filtered, washed with CH₂Cl₂. The pyridinium salt present in solution is removed

by aqueous extraction and the aqueous phase is washed twice with CH_2Cl_2 . The organic fractions are collected, the solvent is evaporated and the pyridine is eliminated by coevaporation with toluene. The isolated product is dried under vacuum. Yield 72%.

5 ^{31}P NMR (CD_2Cl_2) δ 9.78, 9.16 ppm.

MALDI-TOF MS (positive mode, trihydroxyacetophenone as matrix) $[\text{M}+\text{H}]^+$
 $m/z_{\text{exp}} = 1113.16$, $m/z_{\text{calc}} = 1116.11$.

The spectrophotometrical purity determined by HPLC is 99%.

Example 47

10 *Synthesis of the dimer 5'-O-DMTr-dC^{Bz}-T-3'-O-Lev H-phosphonate*

A solution of 5'-OH-T-3'-O-Lev (142.0 mg, 0.417 mmol) and of 5'-O-DMTr-dC^{Bz}-H-phosphonate TEA salt (120.0 mg, 0.500 mmol, 1.2 eq) in 4.0 ml of $\text{CH}_2\text{Cl}_2/\text{py}$ (1:1) is added to polystyrene-bound acid chloride (830.0 mg, 2.1 mmol/g, 4.2 eq) that is suspended in 4.0 ml of the same solvent. The mixture 15 is shaken for 1h at room temperature until the disappearance of the monomers. The reaction is monitored by reverse phase HPLC. The resin is filtered, washed with CH_2Cl_2 . The pyridinium salt present in solution is removed by aqueous extraction and the aqueous phase is washed twice with CH_2Cl_2 . The 20 organic fractions are collected, the solvent is evaporated and the pyridine is eliminated by coevaporation with toluene. The isolated product is dried under vacuum. Yield 100%.

^{31}P NMR (CD_2Cl_2) δ 10.16, 8.72 ppm.

MALDI-TOF MS (positive mode, trihydroxyacetophenone as matrix) $[\text{M}+\text{H}]^+$
 $m/z_{\text{exp}} = 1020.21$, $m/z_{\text{calc}} = 1021.01$.

25 The spectrophotometrical purity determined by HPLC is 99%.

Example 48

Synthesis of the dimer 5'-O-DMTr- dG^{IBu}-dA^{Bz} -3'-O-Lev H-phosphonate

A solution of 5'-OH-dA^{Bz}-3'-O-Lev (189.0 mg, 0.417 mmol) and of 5'-O-DMTr-dG^{IBu}-H-phosphonate TEA salt (402.0 mg, 0.500 mmol, 1.2 eq) in 4.0 ml of $\text{CH}_2\text{Cl}_2/\text{py}$ (1:1) is added to polystyrene-bound acid chloride (830.0 mg, 2.1 mmol/g, 4.2 eq) that is suspended in 4.0 ml of the same solvent. The mixture 30 is shaken for 1h at room temperature until the disappearance of the monomers. The reaction is monitored by reverse phase HPLC. The resin is filtered, washed with CH_2Cl_2 . The pyridinium salt present in solution is removed by aqueous extraction and the aqueous phase is washed twice with CH_2Cl_2 . The 35

organic fractions are collected, the solvent is evaporated and the pyridine is eliminated by coevaporation with toluene. The isolated product is dried under vacuum. Yield 83%.

^{31}P NMR (CD_2Cl_2) δ 6.80, 6.70 ppm.

5 MALDI-TOF MS (positive mode, trihydroxyacetophenone as matrix) $[\text{M}+\text{H}]^+$
 $m/z_{\text{exp}} = 1140.30$, $m/z_{\text{calc}} = 1140.14$.

The spectrophotometrical purity determined by HPLC is 85%.

Example 49

Synthesis of the dimer 5'-O-DMTr-T-T-3'-O-Lev H-phosphonate

10 A solution of 5'-OH-T-3'-O-Lev (142.0 mg, 0.417 mmol) and of 5'-O-DMTr-T-H-phosphonate TEA salt (354.8 mg, 0.500 mmol, 1.2 eq) in 4.0 ml of $\text{CH}_2\text{Cl}_2/\text{py}$ (1:1) is added to polystyrene-bound acid chloride (830.0 mg, 2.1 mmol/g, 4.2 eq) that is suspended in 4.0 ml of the same solvent. The mixture is shaken for 1h at room temperature until the disappearance of the monomers. The reaction is monitored by reverse phase HPLC. The resin is filtered, washed with CH_2Cl_2 . The pyridinium salt present in solution is removed by aqueous extraction and the aqueous phase is washed twice with CH_2Cl_2 . The organic fractions are collected, the solvent is evaporated and the pyridine is eliminated by coevaporation with toluene. The isolated product is dried under 20 vacuum. Yield 98%.

^{31}P NMR (CD_2Cl_2) δ 9.99, 8.55 ppm.

MALDI-TOF MS (positive mode, trihydroxyacetophenone as matrix) no result

The spectrophotometrical purity determined by HPLC is 99%.

Example 50

25 *Synthesis of the trimer 5'-O-DMTr-dG^{tBu}-T-T-3'-O-Lev H-phosphonate*

Detritylation of 5'-O-DMTr-T-T-3'-O-Lev H-phosphonate

The H-phosphonate dimer 5'-O-DMTr-T-T-3'-O-Lev (115 mg, 0.123 mmol) is dissolved in 4.0 ml of $\text{CH}_2\text{Cl}_2/\text{MeOH}$ (7:3) and cooled in an ice bath. To this solution 1.0 ml of a solution of 10% BSA (benzene sulfonic acid) in 30 $\text{CH}_2\text{Cl}_2/\text{MeOH}$ (7:3) is added drop wise under stirring and the progress of the reaction is monitored by TLC. After 15 min the solution is diluted with 20 ml of CH_2Cl_2 and then 0.4 g of poly(4-vinyl-pyridine) are added. The mixture is shaken 5 minutes and the resin is filtered off and washed with CH_2Cl_2 . The product is purified by precipitation from CH_2Cl_2 with ether and dried under

vacuum. Yield 94%.

MALDI-TOF MS (positive mode, trihydroxyacetophenone as matrix) no result

The spectrophotometrical purity determined by HPLC is 99%.

Coupling

5 A solution of 5'-OH-T-T-3'-O-Lev (73.2 mg, 0.116 mmol) and of 5'-O-DMTr-
dG^{IBu}-H-phosphonate TEA salt (140.5 mg, 0.174 mmol, 1.5 eq) in 2.0 ml of
CH₂Cl₂/py (1:1) is added to polystyrene-bound acid chloride (660.0 mg, 2.1
mmol/g, 12 eq) that is suspended in 4.0 ml of the same solvent. The mixture
is shaken for 4h at room temperature until the disappearance of the mono-
mers. The reaction is monitored by reverse phase HPLC. The resin is filtered,
washed with CH₂Cl₂. The pyridinium salt present in solution is removed by
aqueous extraction and the aqueous phase is washed twice with CH₂Cl₂. The
organic fractions are collected, dried over Na₂SO₄, the solvent is evaporated
and the pyridine is eliminated by coevaporation with toluene. The isolated
10 product is dried under vacuum. Yield 55%.

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³¹P NMR (CD₂Cl₂) δ 10.22, 10.07, 9.73, 9.00, 8.84, 8.75, 8.59 ppm.

MALDI-TOF MS (positive mode, trihydroxyacetophenone as matrix) [M+H]⁺
m/z_{exp} = 1312.50, m/z_{calc} = 1315.21.

The spectrophotometrical purity determined by HPLC is 93%.

20 **Example 51**

Synthesis of the tetramer 5'-O-DMTr-dC^{Bz}-dG^{IBu}-T-T-3'-O-Lev H-phosphonate

Detritylation of 5'-O-DMTr-dG^{IBu}-T-T-3'-O-Lev H-phosphonate

The H-phosphonate trimer 5'-O-DMTr-dG^{IBu}-T-T-3'-O-Lev (84 mg, 0,064
mmol) is dissolved in 4.0 ml of CH₂Cl₂/MeOH (7:3) and cooled in an ice bath.
25 To this solution 1.0 ml of a solution of 10% BSA (benzene sulfonic acid) in
CH₂Cl₂/MeOH (7:3) is added drop wise under stirring and the progress of the
reaction is monitored by TLC. After 15 min the solution is diluted with 20 ml of
CH₂Cl₂ and then 0.4 g of poly(4-vinyl-pyridine) are added. The mixture is
shaken 5 minutes and the resin is filtered off and washed with CH₂Cl₂. The
30 product is purified by precipitation from CH₂Cl₂ with ether and dried under
vacuum. Yield 71%.

MALDI-TOF MS (positive mode, trihydroxyacetophenone as matrix) [M+H]⁺
m/z_{exp} = 1012.07, m/z_{calc} = 1012.84.

The spectrophotometrical purity determined by HPLC is 83%.

Coupling

A solution of 5'-OH-dG^{Bu}-T-T-3'-O-Lev *H*-phosphonate (45.9 mg, 0.045 mmol) and of 5'-O-DMTr-dC^{Bz}-*H*-phosphonate TEA salt (54.3 mg, 0.068 mmol, 1.5 eq) in 1.0 ml of CH₂Cl₂/py (1:1) is added to polystyrene-bound acid chloride

5 (260.0 mg, 2.1 mmol/g, 12 eq) that is suspended in 1.5 ml of the same solvent. The mixture is shaken for 3h and 30 minutes at room temperature until the disappearance of the monomers. The reaction is monitored by reverse phase HPLC. The resin is filtered, washed with CH₂Cl₂. The pyridinium salt present in solution is removed by aqueous extraction and the aqueous phase 10 is washed twice with CH₂Cl₂. The organic fractions are collected, dried over Na₂SO₄, the solvent is evaporated and the pyridine is eliminated by coevaporation with toluene. The isolated product is dried under vacuum. Yield 75%.

³¹P NMR (CD₂Cl₂) δ 11.58, 11.11, 10.52, 10.32, 10.14, 9.66, 9.40, 9.14, 8.99, 8.35, 7.40, 7.17, 6.99 ppm.

15 MALDI-TOF MS (positive mode, trihydroxyacetophenone as matrix) [M+H]⁺ m/z_{exp} = 1690.10, m/z_{calc} = 1692.51.

The spectrophotometrical purity determined by HPLC is 92%.

Example 52*Synthesis of the dimer 5'-O-DMTr-dC^{Bz}-dA^{Bz} -3'-O-Lev *H*-phosphonate*

20 A solution of 5'-OH-dA^{Bz}-3'-O-Lev (197.3 mg, 0.435 mmol) and of 5'-O-DMTr-dC^{Bz}-*H*-phosphonate TEA salt (400.0 mg, 0.500 mmol) in 4.0 ml of CH₂Cl₂/py (1:1) is added to polystyrene-bound acid chloride (830.0 mg, 2.1 mmol/g, 4.2 eq) that is suspended in 4.0 ml of the same solvent. The mixture is shaken for 1h at room temperature until the disappearance of the monomers. The reaction 25 is monitored by reverse phase HPLC. The resin is filtered, washed with CH₂Cl₂. The pyridinium salt present in solution is removed by aqueous extraction and the aqueous phase is washed twice with CH₂Cl₂. The organic fractions are collected, the solvent is evaporated and the pyridine is eliminated by coevaporation with toluene. The isolated product is dried under vacuum. Yield 30 95%.

³¹P NMR (CD₂Cl₂) δ 9.94, 8.94 ppm.

MALDI-TOF MS (positive mode, trihydroxyacetophenone as matrix) [M+H]⁺ m/z_{exp} = 1132.14, m/z_{calc} = 1134.13.

The spectrophotometrical purity determined by HPLC is 96%.

Example 53

Synthesis of the trimer 5'-O-DMTr-dG^{IBu}-dC^{Bz}-dA^{Bz}-3'-O-Lev H-phosphonate

Detritylation of 5'-O-DMTr-dC^{Bz}-dA^{Bz}-3'-O-Lev H-phosphonate

The H-phosphonate dimer 5'-O-DMTr-dC^{Bz}-dA^{Bz}-3'-O-Lev (180 mg, 0.158 mmol) is dissolved in 4.0 ml of CH₂Cl₂/MeOH (7:3) and cooled in an ice bath. To this solution 1.0 ml of a solution of 10% BSA (benzene sulfonic acid) in CH₂Cl₂/MeOH (7:3) is added drop wise under stirring and the progress of the reaction is monitored by TLC. After 15 min the solution is diluted with 20 ml of CH₂Cl₂ and then 0.4 g of poly(4-vinyl-pyridine) are added. The mixture is shaken 5 minutes and the resin is filtered off and washed with CH₂Cl₂. The product is purified by precipitation from CH₂Cl₂ with ether and dried under vacuum. Yield 83%.

MALDI-TOF MS (positive mode, trihydroxyacetophenone as matrix) [M+H]⁺ m/z_{exp} = 831.91, m/z_{calc} = 831.75.

15 The spectrophotometrical purity determined by HPLC is 74%.

Coupling

A solution of 5'-OH- dC^{Bz}-dA^{Bz} -3'-O-Lev (109 mg, 0.131 mmol) and of 5'-O-DMTr-dG^{IBu}-H-phosphonate TEA salt (126.5 mg, 0.157 mmol, 1.2 eq) in 2.0 ml of CH₂Cl₂/py (1:1) is added to polystyrene-bound acid chloride (660.0 mg, 2.1 mmol/g, 6 eq) that is suspended in 3.5 ml of the same solvent. The mixture is shaken for 4h at room temperature until the disappearance of the monomers. The reaction is monitored by reverse phase HPLC. The resin is filtered, washed with CH₂Cl₂. The pyridinium salt present in solution is removed by aqueous extraction and the aqueous phase is washed twice with CH₂Cl₂. The organic fractions are collected, dried over Na₂SO₄, the solvent is evaporated and the pyridine is eliminated by coevaporation with toluene. The isolated product is dried under vacuum. Yield 50%.

³¹P NMR (CD₂Cl₂) δ 10.24, 10.06, 9.96, 9.88, 9.44, 9.38, 9.33, 9.28 ppm.

MALDI-TOF MS (positive mode, trihydroxyacetophenone as matrix) [M+H]⁺ m/z_{exp} = 1516.14, m/z_{calc} = 1517.43.

The spectrophotometrical purity determined by HPLC is 74%.

Example 54

Synthesis of dimer 5'-O-DMTr-T-dG^{ibu}-3'-O-Lev H-phosphonate

A solution of 5'-OH-dG^{ibu}-3'-O-Lev (435 mg, 1.0 mmol) and of 5'-O-DMTr-dT-

H-phosphonate TEA salt (850 mg, 1.2 mmol) in 7.0 ml of CH₂Cl₂/py (1:1, v/v) is added to polystyrene-bound acid chloride (1.5g, 2.4 mmol/g, 3 eq) that is suspended in 7.0 ml of the same solvent. The mixture is shaken for 2h15 at room temperature until the disappearance of the monomers. The reaction is 5 monitored by reverse phase HPLC. The resin is filtered, washed with CH₂Cl₂. The pyridinium salt present in solution is removed by aqueous extraction and the aqueous phase is washed twice with CH₂Cl₂. The organic fractions are collected, the solvent is evaporated and the pyridine is eliminated by coevaporation with toluene. The isolated product is dried under vacuum. 914 mg Yield 10 89%.

³¹P NMR (CD₂Cl₂) δ 12.63, 8.92 ppm.

MALDI-TOF MS (positive mode, trihydroxyacetophenone as matrix) [M+H]⁺ m/z_{exp} = 1026.6, m/z_{calc} = 1027.0. The spectrophotometrical purity determined by HPLC is 96%.

15 Example 55

Synthesis of the trimer 5'-O-DMTr- C^{bz}-T-dG^{ibu}-3'-O-Lev H-phosphonate

Detritylation of 5'-O-DMTr-T-dG^{ibu}-3'-O-Lev H-phosphonate

The *H*-phosphonate dimer 5'-O-DMTr- T-dG^{ibu} -3'-O-Lev (430 mg, 0.420 mmol) is dissolved in 8.0 ml of CH₂Cl₂/MeOH (7:3, v/v) and cooled in an ice 20 bath. To this solution 2.0 ml of a solution of 10% BSA (benzene sulfonic acid) in CH₂Cl₂/MeOH (7:3, v/v) is added drop wise under stirring and the progress of the reaction is monitored by TLC. After 20 min the solution is diluted with 50 ml of CH₂Cl₂ and then 0.8 g of poly(4-vinyl-pyridine) are added. The mixture is shaken 5 minutes and the resin is filtered off and washed with CH₂Cl₂. The 25 product is purified by precipitation from CH₂Cl₂ with ether and dried under vacuum. 320mg Yield 100%. The spectrophotometrical purity determined by HPLC is 98%.

Coupling

A solution of 5'-OH- T-dGib^{bu} -3'-O-Lev (320 mg, 0.43 mmol) and of 5'-O- 30 DMTr-dG^{ibu}-*H*-phosphonate TEA salt (413 mg, 0.52 mmol, 1.2 eq) in 4.5 ml of CH₂Cl₂/py (1:1, v/v) is added to polystyrene-bound acid chloride (1050 mg, 2.4 mmol/g, 5 eq) that is suspended in 4.5 ml of the same solvent. The mixture is shaken for 4h at room temperature until the disappearance of the monomers. The reaction is monitored by reverse phase HPLC. The resin is 35 filtered, washed with CH₂Cl₂. The pyridinium salt present in solution is removed by aqueous extraction and the aqueous phase is washed twice with CH₂Cl₂.

The organic fractions are collected, dried over Na_2SO_4 , the solvent is evaporated and the pyridine is eliminated by coevaporation with toluene. The product is purified by precipitation from CH_2Cl_2 with ether and dried under vacuum. 538 mg Yield 89%.

5 ^{31}P NMR (CD_2Cl_2) δ 12.68, 12.46, 10.27, 9.46, 9.40, 9.11, 8.96, 8.92. ppm.

MALDI-TOF MS (positive mode, trihydroxyacetophenone as matrix) $[\text{M}+\text{H}]^+$ $m/z_{\text{exp}} = 1404.0$, $m/z_{\text{calc}} = 1404.3$. The spectrophotometrical purity determined by HPLC is 94%.

EXAMPLE 56

10 *Synthesis of the trimer 5'-O-DMTr- $\text{C}^{\text{bz}}\text{-T-dG}^{\text{ibu}}\text{-3'-O-lev S-phenyl phosphotriester}}$*

To a solution of 5'-O-DMTr- $\text{C}^{\text{bz}}\text{-T-dG}^{\text{ibu}}\text{-3'-O-lev H-phosphonate}$ (110 mg, 0.078 mmol) in 2 ml of CH_2Cl_2 /py (1:1), N-(phenylsulfanyl)phthalimide (80mg, 0.314 mmol, 4 eq) and Triethylamine (200 mL, 10 eq) were added. The reaction is stirred for 3h at room temperature. The solvent is evaporated. The product is purified by precipitation from CH_2Cl_2 with ether and dried under vacuum. 117 mg Yield 92%

15 ^{31}P NMR signals between 24.09 and 25.76 ppm

20 MALDI-TOF MS (positive mode, trihydroxyacetophenone as matrix) $[\text{M}+\text{H}]^+$ $m/z_{\text{exp}} = 1621.8$, $m/z_{\text{calc}} = 1620.6$. The spectrophotometrical purity determined by HPLC is 87%.

EXAMPLE 57

Synthesis of the trimer 5'-O-DMTr- $\text{C}^{\text{bz}}\text{-T-dG}^{\text{ibu}}\text{-3'-O-lev S-cyanoethyl phosphotriester}$

25 The trimer 5'-O-DMTr- $\text{C}^{\text{bz}}\text{-T-dG}^{\text{ibu}}\text{-3'-O-lev H-phosphonate}$ (118 mg, 0.084 mmol) is coevaporated twice with dry pyridine (2x2ml) and dissolved in 2 ml of CH_2Cl_2 /py (1:1). To this solution is added successively triethylamine (6 mL, 0.5eq), trimethylsilyl chloride (100 mL, 0.84 mmol, 10 eq) and N-[(2-cyanoethyl)thio]phthalimide (78 mg, 0.336 mmol, 10 eq).

30 After 1h30 the reaction is complete. The pyridinium salt present in solution is removed by aqueous extraction and the aqueous phase is washed twice with CH_2Cl_2 . The solvent is evaporated. The product is purified by precipitation from CH_2Cl_2 with ether and dried under vacuum. 106 mg Yield 80%

35 ^{31}P NMR signals between 26.86 and 28.75 ppm.

35 MALDI-TOF MS (positive mode, trihydroxyacetophenone as matrix) $[\text{M}+\text{H}]^+$

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$m/z_{exp} = 1574.6$, $m/z_{calc} = 1574.6$. The spectrophotometrical purity determined by HPLC is 84%.

Example 58

GENERAL PROCEDURE FOR THE SYNTHESIS OF 5'-OH-3'-O-Lev CYANOETHYL PHOSPHOROTHIONOTRIESTER BASE PROTECTED DIMERS USING THE PHOSPHORAMIDITE METHOD ON 10 MMOL SCALE

Coupling procedure of 5'-O-DMTr-3'-cyanoethyl-phosphoramidite base protected nucleotide with 5'-OH-3'-O-Lev base protected nucleoside using the poly(4-vinylpyridinium *p*-toluenesulfonate) (Aldrich):

5 10 15 20 25 30 35 40 45 50 55 60 65 70 75 80 85 90 95 100 105 110 115 120 125 130 135 140 145 150 155 160 165 170 175 180 185 190 195 200 205 210 215 220 225 230 235 240 245 250 255 260 265 270 275 280 285 290 295 300 305 310 315 320 325 330 335 340 345 350 355 360 365 370 375 380 385 390 395 400 405 410 415 420 425 430 435 440 445 450 455 460 465 470 475 480 485 490 495 500 505 510 515 520 525 530 535 540 545 550

5'-OH-3'-O-Lev base protected nucleoside (10 mmol) and 5'-O-DMTr-3'-cyanoethyl-phosphoramidite base protected nucleotide (15 mmol, 1.5 eq) are dissolved in anhydrous dichloromethane (100 ml). The solution is transferred under argon in a flask containing the poly(4-vinylpyridinium *p*-toluenesulfonate) (100 mmol PyrH⁺, 10 eq) and shaken. The reaction is followed by reverse phase HPLC and is usually complete between 1h30 and 2h30. The desired 5'-O-DMTr-3'-O-Lev cyanoethyl phosphite triester base protected dimer is characterized by ³¹P NMR. The crude is a mixture of 5'-O-DMTr-3'-O-Lev cyanoethyl phosphite triester base protected dimer and of 5'-O-DMTr-3'-cyanoethyl *H*-phosphonate base protected nucleotide. The poly(4-vinylpyridinium *p*-toluenesulfonate) is filtered off, washed 3 times with 50 ml of CH₂Cl₂ and the solution is concentrated to 100 ml.

Sulfurization: To the resulting solution is added AMBERLYST A26 tetrathionate form (50 mmol S₄O₆²⁻, 5 eq.), and the reaction mixture is shaken. The reaction is followed by reverse phase HPLC and ³¹P NMR and is usually complete between 1h30 and 2h30. The crude is a mixture of 5'-O-DMTr-3'-O-Lev cyanoethyl phosphorothionotriester base protected dimer and 5'-O-DMTr-3'-cyanoethyl diester *H*-phosphonate base protected nucleotide. The resin AMBERLYST A26 tetrathionate form is filtered off and washed 3 times with 50 ml of CH₂Cl₂.

dimers	phosphite triester		phosphorothionotriester	
5'-O-DMTr-Nu-Nu-3'-O- Lev	RT (min)	³¹ P NMR d	RT (min)	³¹ P NMR d
A ^{Bz} -A ^{Bz}	17.81	140.64; 140.46	18.23	68.30 ; 68.24
C ^{Bz} -A ^{Bz}	19.09	140.48; 140.39	19.35, 19.61*	68.31 ; 68.26
G ^{iBu} -T	15.95; 16.14*	143.50; 141.71	16.73; 17.01*	68.65 ; 68.19
G ^{iBu} -A ^{Bz}	16.86	140.34; 140.02	17.30; 17.56*	67.57 ; 67.41

* mixture of Sp and Rp diastereoisomeres

Detritytlation: To the previous solution is added 100 ml of MeOH so that the CH₂Cl₂/MeOH ratio is about 7/3. The mixture is cooled at 0°C. To the resulting 5 solution is added 90 ml (56 mmol, 5.6 eq.) of a solution of benzene sulfonic acid 10 % in CH₂Cl₂/CH₃OH (7/3). The solution is stirred at 0°C. The detritylation is monitored by TLC and reverse phase HPLC. The reaction time is between 30 min and 1h. When the reaction is complete, 100 ml of H₂O is added to the mixture, the solution is shaken for 10 min at 0°C. Then, the reaction is 10 stopped by stirring at 0°C for 10 min with 100 ml of a saturated solution of NaHCO₃. The solution is diluted with 300 ml of CH₂Cl₂. The organic layer is then washed up to 4 times with H₂O / saturated solution of NaHCO₃ in water (1/1), dried with Na₂SO₄ (50g) and evaporated. The crude product is dissolved 15 in 50 ml CH₂Cl₂ and added dropwise to 1 l of diethylether at 0°C to give a white precipitate of the pure desired 5'-OH-3'-O-lev cyanoethyl phosphorothionotriester base protected dimer. The solid is filtered off, washed with 500 ml diethylether and dried under vacuum. The dimer is characterized by ³¹P NMR and by MALDI-TOF. The spectrophotometric purity is determined by reverse phase HPLC at 260 nm.

Dimers	MW (g/mol)	³¹ P-NMR	RT (min)	Dimers performed following this proce- dure	
				Yield	HPLC- Purity
5'-OH-Nu-Nu-3'-O- Lev					
A ^{Bz} -A ^{Bz}	939.91	68.11; 68.06*	10.85	91% (9.5 g)	91%
C ^{Bz} -A ^{Bz}	915.88	68.03; 67.80*	11.32; 11.46*	94% (8.7 g)	91%
G ^{iBu} -T	808.77	68.48 ; 68.09*	9.72	91% (7.4 g)	91%
G ^{iBu} -A ^{Bz}	921.89	68.02 ; 67.80*	10.32 ; 10.68*	98% (10.3 g)	92%

*mixture of Sp and Rp diastereoisomers

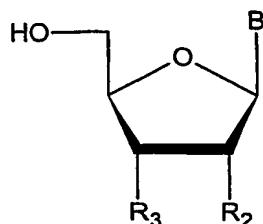
HPLC-Gradient [column: Macherey- Nagel Nucleosil 100-5 C18]:

0 to 5 min --> 10% of CH₃CN to 40% of CH₃CN (in TEAAc 50 mM)
 5 to 20 min --> 40% of CH₃CN to 80% of CH₃CN (in TEAAc 50 mM)
 20 to 25 min --> 80% of CH₃CN to 100% of CH₃CN (in TEAAc 50 mM)

Claims

1. A method for preparing an oligonucleotide comprising the steps of

a) providing a 3'-protected compound having the formula:



5 wherein

B is a heterocyclic base

R₂ is H, a protected 2'-hydroxyl group, F, a protected amino group, an O-alkyl group, an O-substituted alkyl, a substituted alkylamino or a C4'-O2' methylen linkage

10 R₃ is OR'₃, NHR''₃, NR'''₃R''₃, a 3'-protected nucleotide or a 3'-protected oligonucleotide,

R'₃ is a hydroxyl protecting group,

R''₃, R'''₃ are independently an amine protecting group,

15 b) reacting said compound with a nucleotide derivative having a 5'-protection group in the presence of a solid supported activator to give an elongated oligonucleotide with a P(III)-internucleotide bond

c) optionally processing the elongated oligonucleotide with a P(III)-internucleotide bond by either or both of steps c1) and c2) in any sequence

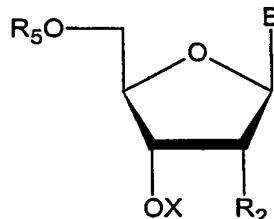
20 c1) capping preferably by reacting with a solid supported capping agent

c2) oxidizing preferably by reacting the oligonucleotide with a solid supported oxidizing reagent

d) removing the 5'-protection group.

25 2. The method of claim 1, wherein the step d) is effected by treatment with a solid supported agent or removing the 5'-protection group with a removal agent followed by addition of a solid supported scavenger or followed by extraction.

3. The method of claim 1 or 2, wherein the nucleotide derivative having a 5'-protection group of step b) has the following formula:



wherein

5 X is a P(III)-function

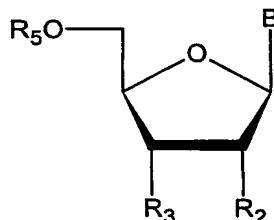
B is a heterocyclic base

R₂ is H, a protected 2'-hydroxyl group, F, a protected amino group, an O-alkyl group, an O-substituted alkyl, a substituted alkylamino or a C4'-O₂'-methylen linkage

10 R₅ is a hydroxyl protecting group, a 5'-protected nucleotide or a 5'-protected oligonucleotide.

4. A method for preparing an oligonucleotide comprising the steps of

a) providing a 5'-protected compound having the formula:



15 wherein

B is a heterocyclic base

R₂ is H, a protected 2'-hydroxyl group, F, a protected amino group, an O-alkyl group, an O-substituted alkyl, a substituted alkylamino or a C4'-O₂'-methylen linkage

20 R₃ is OH, NH₂

R₅ is a hydroxyl protecting group, a 5'-protected nucleotide or a 5'-protected oligonucleotide

b) reacting said compound with a nucleotide derivative having a 3'-

protection group in the presence of a solid supported activator to give an elongated oligonucleotide with a P(III)-internucleotide bond

5 c) optionally processing the elongated oligonucleotide with a P(III)-internucleotide bond by either or both of steps c1) and c2) in any sequence

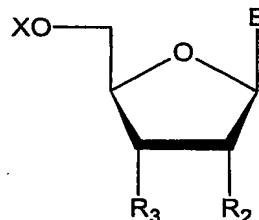
 c1) capping, preferably by reacting with a solid supported capping agent

 c2) oxidizing, preferably by reacting the oligonucleotide with a solid supported oxidizing reagent

 d) removing the 3'-protection group.

10 5. The method of claim 4, wherein step d) is effected by treatment with a solid supported agent or removing the 3'-protection group with a removal agent followed by addition of a solid supported scavenger or followed by extraction.

 6. The method of claim 4 or 5, wherein the nucleotide derivative having a 3'-protection group has the following formula:



15

wherein

X is a P(III)-function

B is a heterocyclic base

20 R₂ is H, a protected 2'-hydroxyl group, F, a protected amino group, an O-alkyl group, an O-substituted alkyl, a substituted alkylamino or a C4'-O2'-methylen linkage

R₃ = OR₃', NHR₃", NR₃R₃'''', a 3'-protected nucleotide or a 3'-protected oligonucleotide,

R₃' is a hydroxyl protecting group,

25 R₃", R₃''' are independently an amine protecting group,

R₃ is a hydroxyl protecting group, a 3'-protected nucleotide or a 3'-protected oligonucleotide

7. The method of any one of claims 1 to 5, comprising the further step of
 - e) repeating steps a) to d) at least once.
8. The method of any one of claims 1 to 6, wherein the nucleotide derivative of step b) is a phosphoramidite or a H-phosphonate.
- 5 9. The method of any one of steps 1 to 8, wherein the solid supported activator of step b) is selected from the group consisting of a solid support bearing a pyridinium salt, a cation exchange solid support with an optionally substituted pyridinium, a cation exchange solid support with an optionally substituted imidazolium salt, a solid support bearing an optionally substituted azole (imidazol, triazole, tetrazole), a salt of a weak base anion exchange resin with a strong acid, a weak cation exchange resin (carboxylic) in its protonated form, a solid support bearing an optionally substituted phenol, a solid support bearing a carboxylic acid chloride/bromide, a sulfonic acid chloride/bromide, a chloroformate, a bromoformate, a chlorosulfite, a bromosulfite, a phosphorochloridate, a phosphorbromidate and a solid support bound carbodiimide.
- 10 10. The method of any one of claims 1 to 9, wherein the solid supported oxidizing reagent is selected from the group consisting of solid supported periodates, permanganates, osmium tetroxides, dichromates, hydroperoxides, substituted alkylamine oxides, percarboxylic acid and persulfonic acid.
- 15 11. The method of any one of claims 1 to 10, wherein the oxidizing is a sulfurization.
12. The method of claim 11, wherein the solid supported oxidizing reagent is selected from the group consisting of a solid supported tetrathionate, a solid supported alkyl or aryl sulfonyl disulfide, a solid supported optionally substituted dibenzoyl tetrasulfide, a solid supported bis(alkyloxythiocarbonyl)tetrasulfide, a solid supported optionally substituted phenylacetyl disulfide, a solid supported N-[(alkyl or aryl)sulfanyl] alkyl or aryl substituted succinimide and a solid supported (2-pyridinylidithio) alkyl or aryl.
- 20 25 30 13. The method of any one of claims 1 to 12, wherein the solid supported capping agent is a solid supported activated acid, preferably a carboxylic acid chloride, carboxylic acid bromide, azolide, substituted azolide, anhydride or chloroformate or phosphorochloridate, or a solid supported phosphoramidite, or a solid supported H-phosphonate monoester.

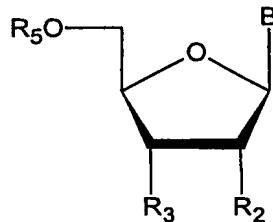
14. The method of any one of claims 1 to 13, wherein the 5'-protection is a dimethoxytrityl group (DMTr) or a monomethoxytrityl group (MMTr) and the solid supported agent of step d) is an cationic ion exchanger resin in the H⁺ form or solid supported ceric ammonium nitrate.

5 15. The method of any one of claims 1 to 14, wherein the 3'-protection is a silyl group and the solid supported agent of step d) is an anionic ion exchanger resin in the F-form or the 3'-protection is levulinic acid and the solid supported agent of step d) is a solid supported hydrazine or a solid supported hydrazinium.

10 16. Use of a solid supported sulfurization agent consisting of solid supported amine and a tetrathionate having the formula S₄O₆ or a cyanoethylthiosulfate (NC-CH₂-CH₂-S-SO₃) for sulfurization of oligonucleotides.

17. A method for preparing an oligonucleotide comprising the steps of

a) providing a compound having the formula:



15

wherein

B is a heterocyclic base

20

R₂ is H, a protected 2'-hydroxyl group, F, a protected amino group, an O-alkyl group, an O-substituted alkyl, a substituted alkylamino or a C4'-O2' methylen linkage

and

R₃ is OR'₃, NHR"3, NR"3R'''3,a protected nucleotide or a protected oligonucleotide and R₅ is a P(III) function

25

R'3 is a hydroxyl protecting group,

R"3, R'''3 are independently an amine protecting group,

or

R₅ is a hydroxyl protecting group, a protected nucleotide or a protected oligonucleotide and R₃ is a P(III) function

- b) reacting said compound with a nucleotide derivative having a 3' or 5'-free OH-group in the presence of a solid supported activator to give an elongated oligonucleotide with a P(III)-internucleotide bond
- 5 c) optionally processing the elongated oligonucleotide with a P(III)-internucleotide bond by either or both of steps c1) and c2) in any sequence
 - c1) capping by reacting with a solid supported capping agent
 - c2) oxidizing by reacting the oligonucleotide with a solid supported oxidizing reagent
- 10 d) removing the 3' or 5'-protection group.

INTERNATIONAL SEARCH REPORT

International Application No.
PCT/EP 03/08447

A. CLASSIFICATION OF SUBJECT MATTER
IPC 7 C07H21/00

According to International Patent Classification (IPC) or to both national classification and IPC

B. FIELDS SEARCHED

Minimum documentation searched (classification system followed by classification symbols)
IPC 7 C07H

Documentation searched other than minimum documentation to the extent that such documents are included in the fields searched

Electronic data base consulted during the International search (name of data base and, where practical, search terms used)

EPO-Internal, WPI Data, PAJ, CHEM ABS Data

C. DOCUMENTS CONSIDERED TO BE RELEVANT

Category	Citation of document, with indication, where appropriate, of the relevant passages	Relevant to claim No.
X	WO 99 52926 A (TRIAS JOAQUIM ; ROSENOW CARSTEN (US); VERSICOR INC (US); YOUNG DENN) 21 October 1999 (1999-10-21) the whole document, in particular: claims 31-40; page 5, lines 1-6; Figure 15	1,3,4, 6-9,14, 17 1-9,17
X	WO 01 51532 A (UNIV MICHIGAN) 19 July 2001 (2001-07-19)	1,3,4, 6-9,14, 17
Y	the whole document, in particular: claims 39-63; Figure 21	1-9,17

	-/-	

Further documents are listed in the continuation of box C:

Patent family members are listed in annex:

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Date of the actual completion of the International search

24 October 2003

Date of mailing of the International search report

03/11/2003

Name and mailing address of the ISA
European Patent Office, P.B. 5818 Patentlaan 2
NL - 2280 HV Rijswijk
Tel. (+31-70) 340-2040, Tx. 31 651 epo nl,
Fax: (+31-70) 340-3016

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INTERNATIONAL SEARCH REPORT

International Application No.
PCT/EP 03/08447

C.(Continuation) DOCUMENTS CONSIDERED TO BE RELEVANT

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Y	the whole document, in particular: claims 5,8; column 6, lines 53-56	1-9,17
Y	US 5 808 042 A (TAN WEITIAN ET AL) 15 September 1998 (1998-09-15) cited in the application the whole document	1-9,17
Y	WO 99 62922 A (MANOHARAN MUTHIAH ;RAVIKUMAR VASULINGA T (US); SANGHVI YOGESH (US)) 9 December 1999 (1999-12-09) the whole document, in particular: claims 10,11; pages 65-66, example 5	1-9,17
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Information on patent family members

International application No.

PCT/EP 03/08447

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